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ATIKOKAN TGS AQUATIC STUDIES, 1981 to 1988 II: WATER CHEMISTRY

Report No 89-276-K

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ABSTRACT

Comparison of chemical data collected prior to and during the operation of Atikokan TGS indicated that changes in many chemical parameters were a reflection of the relocation of water through the station from Moose and Marmion Lakes into Snow, Icy and Abie Lakes. This trend was most apparent for conservative parameters such as alkalinity, calcium, chloride, dissolved solids and hardness but for more dynamic parameters such as total phosphorus the trend was only apparent when the station was consistently operating. Most hypothesized effects of station operation on water chemistry were considered incorrect due to the substantial influence of water relocation on the chemistry of the lakes. With the exception of iron, the frequency of exceedances of provincial water quality objectives did not increase during operation of the station.

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EXECUTIVE SUMMARY

ATIKOKAN TGS AQUATIC STUDIES, 1981 to 1988 II: WATER CHEMISTRY

G.T. Haymes

Atikokan Thermal Generating Station (TGS) consists of one 200 MW lignite-fired unit. The condenser-cooling-water for Atikokan TGS is drawn at a maximum rate of 6.6 m^3 per second from approximately the 10-m depth of Moose Lake and discharged at the surface into Snow Lake. The discharge water circulates through Snow, Icy, Abie and Marmion Lakes before returning to Moose Lake. At the request of Environmental Studies and Assessments Department, pre and postoperational aquatic studies at Atikokan TGS were initiated in 1981 and were completed in 1988. This report presents chemical data collected during 1987 and 1988, integrates the chemical data from the entire study and evaluates the effects of the station on the water chemistry of the cooling circuit.

As in previous study years, levels of several parameters were lowest in Slush Lake, lying outside the cooling water circuit; however, unlike earlier years, levels of most parameters were similar among the remaining locations within the cooling circuit. In previous years many parameters were highest in one of the small lakes in the cooling circuit. Conservative parameters, including hardness, conductivity, alkalinity, calcium, sodium, magnesium, potassium, chloride, soluble silica, dissolved solids and total organic and inorganic carbon, either increased or decreased in Snow, Icy and Abie Lakes during 1987 to more closely resemble levels in Marmion Lake where levels were relatively constant throughout the study. It would appear that these changes are a reflection of mass water movements from Moose and Marmion Lakes into Snow, Icy and Abie Lakes via the Atikokan TGS cooling water system. Bottom water chemistry in Snow, Icy and Abie Lakes reacted in a similar fashion to that of the surface samples indicating a fair degree of mixing of the station discharge through the water column.

Total phosphorus in surface waters tended to vary substantially among locations in each year up to 1988 when levels were similar among locations as occurred with the parameters above. The absence of this similarity among locations in 1987, was likely the result of the less consistent operation of the station during 1987 than during 1988. Phosphorus is a relatively dynamic nutrient and likely returns to levels more characteristic of the lake basin when the station is not operating.

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Differences in other parameters among years did not appear to be directly related to station operation. pH levels increased at most locations after 1981. This increase in pH was coincident with a decline in sulphate ion. Among the remaining parameters analyzed, turbidity decreased at most locations in 1987, while Kjeldahl nitrogen was relatively stable among years at all locations with the exception of 1982 when values at all locations were substantially lower than other years.

Chemicals (boiler-cleaning fluids, for example) used during the commissioning of the station were discharged into the Lower Basin of Moose Lake. The Lower Basin is virtually isolated from the cooling water circuit and the Seine River drainage basin. Analysis of water samples collected prior to and during the commissioning period indicated that, with the exception of suspended and dissolved iron, levels of most parameters measured became similar to or fell below predischarge levels as distance from the point of discharge increased. Copper was above predumping levels on one sampling occasion; although, levels measured subsequently were below levels measured before dumping. Nickel was the only parameter which was measured at higher levels on the last sampling date (0.006 ppm, October, 1985) relative to predumping measurements (less than 0.005 ppm).

Generally, the number of exceedances of provincial water quality guidelines measured in 1987 was below that of preoperational years. The lone exception to this generality was iron.

During a workshop involving representatives from the Ministries of Natural Resources and Environment and from Ontario Hydro, a number of hypotheses of effect were developed. These hypotheses consisted of a series of linkages from an action associated with operation or construction of the station to an eventual effect on a valued ecosystem component. Several of these hypotheses referred to effects on water quality. Generally, the predicted effects on water quality of the cooling circuit were not substantiated by the current data. The primary effect of station operation was to make the chemistry of the circuit more homogeneous which was generally in contradiction to the hypothesized effects.

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ATIKOKAN TGS AQUATIC STUDIES 1981 TO 1988 II: WATER CHEMISTRY

G.T. Haymes

1.0 INTRODUCTION

Atikokan Thermal Generating Station (TGS) consists of one 200 MW lignite-fired unit. The condenser-cooling-water for Atikokan TGS is drawn at a maximum rate of 6.6 m^3 per second from approximately the 10-m depth of Moose Lake and discharged at the surface into Snow Lake. The discharge water circulates through Snow, Icy, Abie and Marmion Lakes before returning to Moose Lake (Figure 1).

At Ontario Hydro generating stations, aquatic studies are conducted for three years prior to commissioning of the first unit and for three years following commissioning of the final unit. Less intensive studies are also conducted during the commissioning of the station. The purpose of these studies, as requested by Environmental Studies and Assessments Department, is to identify changes in components of the aquatic environment which may be attributable to the construction or operation of the generating station.

Pre and postoperational aquatic studies at Atikokan TGS were initiated in 1981 and were completed in 1988. Results of studies conducted since 1981 are presented in Haymes 1983, 1984, 1985a, 1985b and 1986 and Haymes and Kwik 1987 and 1988.

The design of the postoperational studies was based, primarily, on the results of a workshop held in 1984 to discuss the potential impacts of Atikokan TGS on the environment (Greig et. al. 1984).

During the postoperational phase the operation of the station increased from 2-shift, 5 days per week operation to 3-shift, 7 days per week operation (Haymes 1989).

The study area consists of the five lakes of the cooling circuit; Snow, Icy, Abie, Marmion and Moose and two locations outside the direct influence of the cooling circuit, Slush Lake and Lower Seine Bay on Marmion Lake (Figure 1). The study lakes, particularly Marmion and Moose Lakes, have been altered substantially over the past 60 years due to industrial and mining activities in the area. Details of these perturbations are presented elsewhere (Haymes 1989).

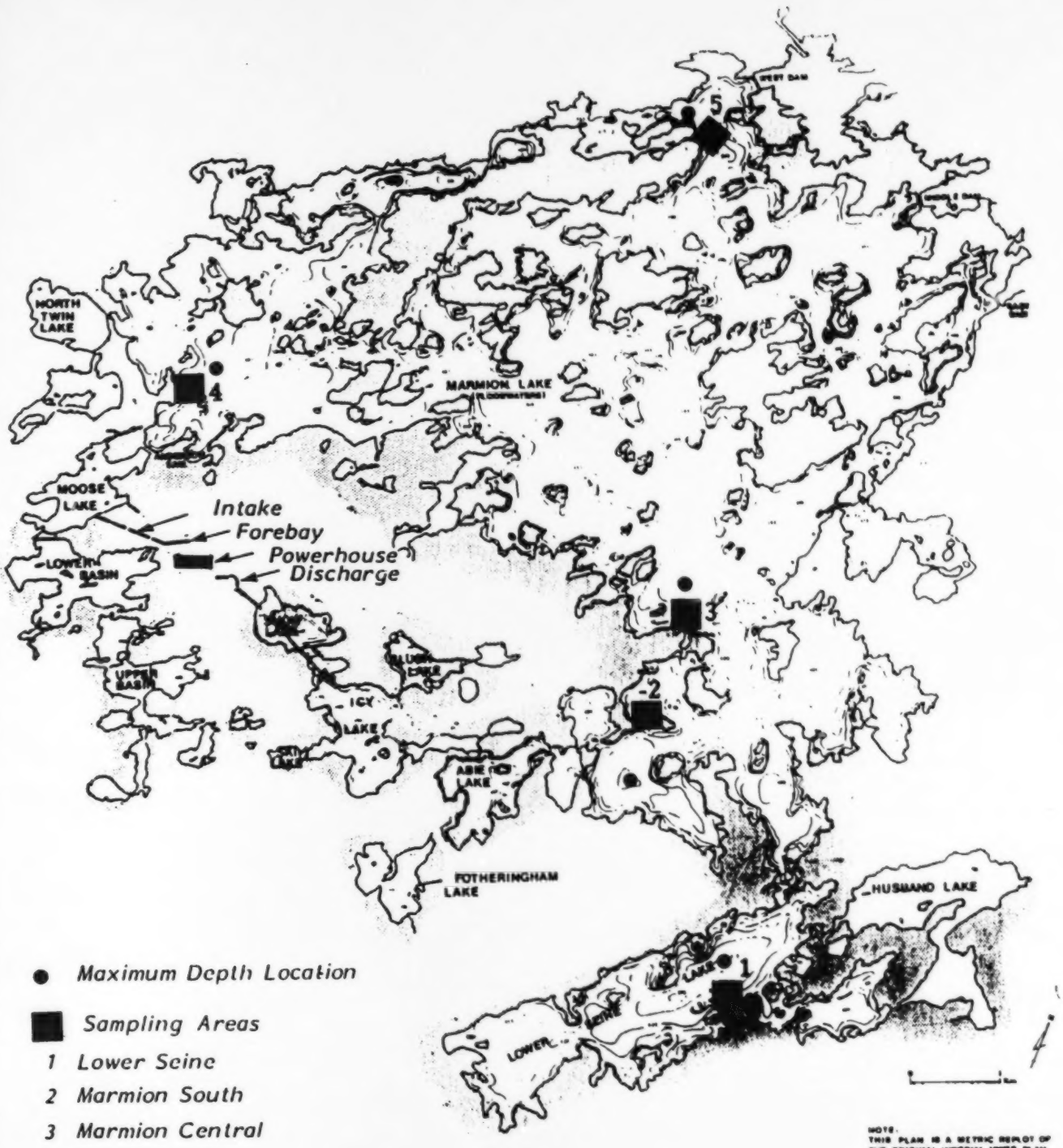

FIGURE 1

ATIKOKAN SAMPLING LOCATIONS

This report presents chemical data collected during 1987 and 1988, integrates the chemical data from the entire study and evaluates the effects of the station on the water chemistry of the cooling circuit.

2.0 METHODS AND MATERIALS

2.1 Cooling Circuit Sampling

The chemical parameters measured during the study varied slightly among years (Table 1) as did the locations sampled and the timing of sampling (Table 2).

Surface and bottom water samples were collected in a Van Dorn bottle and analyzed by the Analytical Chemistry Section of the Research Division using standard techniques.

Statistical comparisons of surface and bottom water chemical parameters among years were made using one-way analysis of variance and Duncan's multiple range tests. Parameters were selected for comparison based on the number of measurements above the limits of detection and the limits of detection remaining consistent measurements. Observations below the limit of detection were listed as the limit of detection for purposes of these analyses. Each basin was analyzed individually and the seasonal measurements were considered replicates. This would tend to make the analysis conservative (i.e. less likely to generate significant differences) as seasonal variation is not taken into account.

2.2 Commissioning Fluids

Surface water samples were collected from the Lower Basin of Moose Lake before (January 1984) and after (May, August and October 1985) discharging of commissioning fluid wastes. Sampling occurred at the mouth of the discharge stream from the station to the Lower Basin (post-discharge, only) and at 2 or 4 locations along a transect from the discharge stream to the centre of the basin. Parameters measured on at least one sampling occasion included pH, total dissolved solids, suspended, dissolved and total iron, copper, nickel, ammonia, citric acid, total and soluble phosphorus, BOD_5 and COD.

3.0 RESULTS

3.1 1987 and 1988 Results

Results of chemical analysis of surface and bottom water samples collected during 1987 and in March, 1988 are listed in Appendix 1 and summarized in Tables 3 and 4. Results from 1988 are listed in Table 5. As in previous study years, levels of several parameters were lowest in Slush Lake; however, unlike earlier years, levels of most parameters were similar among the remaining locations. In previous years many parameters were highest in one of the small lakes in the cooling circuit.

The low values in Slush Lake are consistent with its oligotrophic and headwater nature. On average, conductivity, alkalinity, hardness, total silica, chloride, sulphate, total inorganic carbon, calcium, magnesium, sodium, and potassium were lower in both surface and bottom samples from Slush Lake than from the other sampling basins. Similarly, total phosphorus was lower in surface samples while dissolved solids and ammonia were lower in bottom samples from Slush Lake.

TABLE 1

CHEMICAL PARAMETERS MEASURED - ATIKOKAN 1981-1988

PARAMETER	YEAR						
	1981	1982	1983	1985	1986	1987	1988
pH	X	X	X	X	X	X	X
Conductivity	X	X	X			X	
Alkalinity	X	X	X			X	
Hardness	X	X	X			X	
Chloride	X	X	X			X	
Sulphate	X	X	X			X	
Calcium	X	X	X			X	
Magnesium	X	X	X			X	
Sodium	X	X	X			X	
Potassium	X	X	X			X	
Aluminum	X	X	X			X	
Manganese	X	X	X			X	
Zinc	X	X	X			X	
Copper	X	X	X			X	
Nickel	X	X	X			X	
Arsenic	X	X	X			X	
Selenium	X	X	X			X	
Suspended Iron	X	X	X			X	
Dissolved Iron	X	X	X			X	
Mercury	X	X	X			X	
Turbidity	X	X	X			X	
Total Suspended Solids @105	X	X	X			X	
Total Suspended Solids @550	X	X	X			X	
Total Dissolved Solids @105	X	X	X			X	
Total Dissolved Solids @550	X	X	X			X	
Total Phosphorus	X	X	X	X	X	X	X
Soluble Phosphorus	X	X	X	X	X	X	X
Particulate Phosphorus	X						
Total Kjeldahl Nitrogen	X	X	X	X	X	X	X
Nitrate	X	X	X	X	X	X	X
Nitrite	X					X	
Ammonia	X	X	X				
Particulate Nitrogen	X						
Soluble Nitrogen	X						
Total Silica	X	X	X			X	
Soluble Silica	X	X	X			X	
Total Inorganic Carbon	X	X	X			X	
Total Organic Carbon	X	X	X			X	

TABLE 2

CHEMICAL SAMPLING LOCATIONS AND PERIODS - ATIKOKAN 1981-1988

LOCATION	1981	1982	1983	1985	1986	1987	1988
Snow		MAO	MAOJa	AO	MAO	MAOMr	JAO
Icy	JSNF	MAO	MAOJa	AO	MAO	MAOMr	JAO
Abie		AO	MAOJa	AO	MAO	MAO	JAO
Slush	SNF	MAO	MAOJa	AO	MAO	MAO	JAO
Marmion S.	JSNF	MAO	MAOJa	AO	MAO	MAOMr	JAO
Marmion N.	JSNF	MAO	MAOJa	AO	MAO	MAOMr	JAO
Anderson Dam	JSNF	MAO	MAOJa	AO	MAO	MAOMr	JAO
Lower Seine	JSNF						
Moose				AO	MAO	MAO	JAO

M-May J-June A-August S-September O-October N-November
Ja-January F-February Mr-March

TABLE 3

MEAN AND RANGE OF CHEMICAL PARAMETERS MEASURED IN SURFACE SAMPLES
ATIKOKAN 1987-MARCH 1988

	SNOW			ICY			ABIE			SLUSH			MARMION SOUTH			MARMION NORTH		ANDERSON DAM			MOOSE		
	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX
pH	7.5	7.3	7.7	7.5	7.4	7.7	7.6	7.5	7.7	7.5	7.3	7.8	7.4	7.1	7.5	7.4	7.3	7.5	7.6	7.3	7.9	7.5	7.5	7.5
Conductivity (mS/m)	9.6	8.5	10.3	10	8.8	10.6	7.5	4.2	9.5	5.1	4.7	5.4	9.6	9	10.2	9.3	8.7	9.7	9.3	8.4	9.7	8.9	8.4	9.4
Tot Alkalinity (mg/L-CaCO3)	38	36	41	39	38	42	38	38	39	22	21	23	37	34	42	37	35	41	38	36	42	37	36	39
Turbidity (NTU)	0.56	0.15	0.8	0.6	0.2	1.1	0.77	0.62	1	0.73	0.47	0.95	0.59	0.18	0.85	0.45	0.19	0.85	1.1	0.19	2.25	0.63	0.5	0.7
Susp Solids @105 (mg/L)	<2.3	0.8	3.6	2	1	3.2	<2	<2	2	<1	<1	<2	<1.7	0.8	2.8	<1.4	0.8	<2	3	1.2	4.8	4.5	2	8.6
Susp Solids @550 (mg/L)	<1.7	<0.4	2.8	1.7	1.2	2	<1.5	<1	<2	<2	1	<2	<1.2	0.4	<2	<1.1	0.4	<2	<1.9	<0.4	4.2	4.7	2	7.3
Dis Solids @105 (mg/L)	81	56	138	64	56	72	47	12	65	38	34	45	66	56	74	62	58	66	62	42	80	40	9	67
Dis Solids @550 (mg/L)	43	28	52	50	38	60	17	11	22	20	16	24	50	40	66	47	38	56	34	8	48	<14	<5	22
Total Phosphorus (ppb)	11	5	17	14	9	20	18	14	23	<8	<5	13	16	13	20	13	8	19	<14	<5	27	11	6	16
Soluble Phosphorus (ppb)	<7	<5	13	<6	<5	10	<5	<5	5	<6	<5	9	<7	<5	10	<6	<5	9	<8	<5	16	<5	<5	<5
Kjeldahl Nitrogen (ppm)	0.37	0.23	0.52	0.34	0.24	0.42	0.44	0.3	0.71	0.34	0.21	0.56	0.37	0.24	0.55	0.39	0.23	0.62	0.32	0.19	0.58	0.37	0.19	0.64
Nitrite (ppm-NO2)	<0.02	<0.01	0.04	<0.02	<0.01	0.04	<0.02	<0.01	0.03	<0.02	<0.01	0.04	<0.02	<0.01	0.04	<0.02 <	<0.01	0.04	<0.04	<0.01	0.11	<0.02	<0.01	0.03
Nitrate (ppm-NO3)	0.04	0.01	0.09	<0.03	<0.01	0.05	<0.02	<0.01	0.04	<0.02	<0.01	0.03	<0.08	<0.01	0.28	<0.03 <	<0.01	0.09	<0.01	<0.01	0.01	0.02	0.01	0.04
Ammonia (ppb)	<33	<10	70	<16	<10	26	<28	<10	65	<23	<10	40	<17	<10	27	<27	<10	40	<31	<10	60	29	20	47
Total Silica (ppm)	2	1.2	2.8	1.7	1.4	1.9	2	1	2.5	1.5	0.6	2.2	2.1	1.8	2.4	2	1.4	2.7	2.3	2	2.6	2.1	1.8	2.3
Soluble Silica (ppm)	1.8	1.1	2.2	1.6	0.9	1.9	2	1.5	2.4	1.5	0.6	2.1	2	1.8	2.3	2	1.4	2.8	2.2	2	2.5	2.2	1.9	2.4
Chloride (ppm)	2.5	1.83	3.92	1.76	0.58	2.37	2.1	1.87	2.46	0.4	0.3	0.58	1.85	1.6	2.11	1.73	1.5	1.84	1.74	1.53	2	1.91	1.84	2.02
Sulphate (ppm)	6.58	5.47	8.21	5.79	2.1	8.48	6.22	5.98	6.36	2.09	2.07	2.1	6.56	5.88	7.86	5.88	5.3	6.93	6.18	5.52	7.37	5.99	5.93	6.1
Tot Inorg Carbon (mg/L)	9.6	9	10	9.9	9	11	7.6	3.5	10	5.6	5.2	6.2	9.5	8.6	10	9.2	8.6	10	9.6	9	10.5	7	2.2	10
Tot Org Carbon (mg/L)	5.8	5.3	6.3	6	5.8	6.2	5.2	3.2	7	6.6	6.1	7.2	5.8	5.6	6	5.6	5.3	6	6.2	5.4	7	4.6	2.1	6.2
Hardness (mg/L-CaCO3)	44	41	47	44	41	46	42	41	44	23	22	24	44	40	54	43	39	50	43	41	45	42	41	44
Calcium (ppm)	13	12	14	13	12	13	12	12	13	7.8	7.5	8	12	12	14	12	11	13	12	12	13	12	12	13
Magnesium (ppm)	3	2.73	3.45	3	2.71	3.42	2.8	2.73	2.9	0.93	0.9	0.96	3.3	2.78	4.8	3.18	2.79	4.34	3.11	2.78	3.77	2.8	2.8	2.9
Sodium (ppm)	2.3	2.2	2.5	2.5	2.3	2.9	2.5	2.3	2.7	0.68	0.65	0.69	2.3	2.1	2.5	2.2	2	2.4	2.2	2	2.5	2.2	2	2.4
Potassium (ppm)	0.74	0.7	0.75	0.74	0.72	0.76	0.73	0.7	0.75	0.37	0.33	0.42	0.74	0.68	0.88	0.73	0.66	0.79	0.74	0.71	0.8	0.72	0.7	0.74
Aluminum (ppm)	<1	<1	1	<1	<1	1	<1	<1	1	<1	<1	1	<1	<1	1	<1	<1	1	<1	<1	1	<1	<1	1
Manganese (ppm)	<0.05	<0.05	0.05	<0.06	<0.04	0.09	<0.05	<0.05	0.06	<0.05	<0.05	<0.05	<0.09	<0.05	0.2	<0.09 <	<0.05	0.2	<0.05	<0.05	0.06	<0.05	<0.05	<0.05
Zinc (ppm)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02 <	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Copper (ppb)	<2	<1	3	<2	<1	4	<2	1	4	<2	<1	4	<2	<1	4	<5	<1	12	<2	<1	2	<4	<1	9
Nickel (ppb)	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	-5	<5	<5	<5
Arsenic (ppb)	<1	<1	1	<1	<1	2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Selenium (ppb)	<1	<1	<1	<1	<1	2	<1	<1	<1	<2	<1	4	<1	<1	<1	<1	<1	1.5	<1	<1	1	<1	<1	1.5
Suspended Iron (ppm)	0.03	0.007	0.08	0.009	0.007	0.01	0.022	0.005	0.05	0.006	0.005	0.006	0.006	0.005	0.009	0.004 0	0.003	0.006	0.009	0.001	0.018	0.008	0.007	0.009
Dissolved Iron (ppm)	<0.29	<0.05	1	<0.08	<0.05	0.16	0.08	0.07	0.08	<0.05	<0.05	0.05	<0.05	<0.05	0.06	<0.08 <	<0.05	0.15	<0.09	<0.05	0.13	0.07	0.05	0.1
Mercury (ppb)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

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TABLE 4

MEAN AND RANGE OF CHEMICAL PARAMETERS MEASURED IN BOTTOM SAMPLES
ATIKOKAN 1987-MARCH 1988

	SNOW			ICY			ABIE			SLUSH			MARMION SOUTH			MARMION NORTH		ANDERSON DAM			MOOSE		
	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN MAX	MEAN	MIN	MAX	MEAN	MIN	MAX
pH	7.1	6.7	7.6	7.2	6.6	7.6	7.6	7.5	7.6	7	6.8	7.5	7.1	6.8	7.5	7	6.5 7.7	7.4	7	7.7	7.2	6.9	7.6
Conductivity (mS/m)	10.1	9	11	10.5	9.9	10.9	9.5	8.6	10.3	5.2	4.9	5.5	10	9.5	10.7	9.6	8.6 10.3	9.8	9.4	10.2	9.7	9.6	9.9
Tot Alkalinity (mg/L-CaCO3)	40			10			38			21			34			33		36			36		
Turbidity (NTU)	1.7	0.17	4.5	1.3	0.22	2.4	1	0.57	1.8	0.91	0.8	1	0.58	0.22	0.9	1.1	0.44 2.2	2.3	0.3	4.2	0.62	0.54	0.71
Susp Solids @105 (mg/L)	<5.3	<2	9.6	<4.8	<2	10	2	1	2	<1.5	1	<2	<1.9	<1	2.8	<1.6	<1 <2	3.5	1.6	6	<1.8	<1	2.4
Susp Solids @550 (mg/L)	<3.3	1.6	6.4	<3.3	1.6	6.4	<2	<1	<2	<2	<1	<2	<1.3	0.8	<2	<1.5	<1 <2	-2.1	<1	4	<1.6	1.2	<2
Dis Solids @105 (mg/L)	66	58	74	72	64	84	66	62	70	38	24	48	66	63	70	56	44 62	72	46	125	60	54	68
Dis Solids @550 (mg/L)	38	30	43	49	42	54	28	14	42	13	4	21	52	44	60	38	18 56	36	16	52	30	20	39
Total Phosphorus (ppb)	22	11	37	30	19	44	15	11	21	17	12	19	17	14	20	16	14 19	20	13	24	14	7	22
Soluble Phosphorus (ppb)	<8	<5	16	<7	<5	11	<7	<5	11	<6	<5	7	<8	<5	15	<6	<5 10	<9	<5	14	<9	<5	16
Kjeldahl Nitrogen (ppm)	0.35	0.22	0.61	0.31	0.15	0.52	0.35	0.24	0.51	0.32	0.15	0.5	0.46	0.23	0.67	0.36	0.2 0.51	0.39	0.3	0.56	0.41	0.25	0.59
Nitrite (ppm-NO2)	<0.03	<0.01	0.08	<0.04	<0.01	0.13	<0.02	<0.01	0.03	<0.02	<0.01	0.04	<0.02	<0.01	0.04	<0.02	< <0.01 0.04	<0.02	<0.01	0.04	<0.02	<0.01	0.04
Nitrate (ppm-NO3)	0.04	0.01	0.06	0.08	0.01	0.29	0.02	0.02	0.03	<0.02	<0.01	0.03	<0.09	<0.01	0.28	<0.3	< <0.01 1.16	-0.12	<0.01	0.45	0.21	0.05	0.4
Ammonia (ppb)	35	10	70	46	<10	100	<41	<10	84	<14	<10	20	16	<10	34	<19	<10 37	<22	<10	49	<22	<10	46
Total Silica (ppm)	2.9	2.2	4.3	2.2	1.6	2.8	2.4	1.9	2.7	2.4	1.6	2.8	3.3	2.5	4.5	3.1	2.4 4.4	2.5	1.5	3.5	2.5	1.9	3
Soluble Silica (ppm)	2.7	1.9	3.8	2	1.6	2.8	2.4	2.1	2.7	2.1	1	2.8	3.3	2.4	4.3	3.1	2.7 4.2	2.5	1.4	3.2	2.4	1.7	3.1
Chloride (ppm)	2.04	1.75	2.32	2.37	2	2.93	2	1.96	2.05	0.35	0.25	0.5	1.95	1.58	2.26	1.72	1.49 1.97	1.83	1.67	2.04	1.78	1.49	1.96
Sulphate (ppm)	6.2	3.6	8.6	6.56	5.02	7.57	6.12	5.84	6.55	2.07	1.97	2.21	6.72	5.84	7.61	5.96	5.4 6.98	6.11	5.66	7.08	6.16	5.71	6.41
Tot Inorg Carbon (mg/L)	10.9	9.4	12.3	10.3	9.4	11	10	9	11	6.2	5.5	7.1	9.5	8.9	10	9.8	8.7 11	10.1	9.3	11.4	9.7	9.2	10.4
Tot Org Carbon (mg/L)	5.9	5.6	6.3	6.2	5.8	6.7	6.1	5.6	6.8	6.4	5.7	7.3	5.9	5.3	6.5	5.6	5.4 6	5.5	5	6.1	5.8	5.2	6.4
Hardness (mg/L-CaCO3)	47	44	51	46	44	47	42	41	44	24	23	25	43	41	48	44	39 54	44	39	51	42	42	42
Calcium (ppm)	14	13	15	13	13	14	12	12	13	8	8	9	13	12	14	12	11 12	12	11	14	12	12	12
Magnesium (ppm)	3.22	2.93	3.65	3.13	2.98	3.33	2.84	2.73	2.9	0.97	0.93	1	2.92	2.79	3.2	3.55	2.78 5.83	3.14	2.74	3.91	2.9	2.89	2.9
Sodium (ppm)	2.5	2.1	2.9	2.5	2.3	2.9	2.4	2.2	2.6	0.66	0.64	0.7	2.4	2.1	2.8	2.2	2 2.4	2.2	2	2.5	2.2	2	2.4
Potassium (ppm)	0.79	0.72	0.9	0.77	0.7	0.86	0.71	0.69	0.74	0.39	0.36	0.42	0.73	0.69	0.76	0.71	0.66 0.76	0.76	0.72	0.79	0.74	0.72	0.76
Aluminum (ppm)	<1	<1	1	<1	<1	1	<1	<1	1	<1	<1	1	<1	<1	1	<1	<1 1	<1	<1	1	<1	<1	1
Manganese (ppm)	<0.65	<0.05	2.2	0.58	<0.05	2.13	<0.07	<0.05	0.1	0.06	0.05	0.09	0.16	0.05	0.36	0.23	0.1 0.45	<0.27	<0.05	0.63	<0.09	<0.05	0.17
Zinc (ppm)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	< <0.02 <0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Copper (ppb)	<3	<1	5	<2	<1	5	<2	<1	3	<2	<1	4	<1	<1	2	<3	<1 5	<4	<1	12	<1	<1	2
Nickel (ppb)	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5 <5	<5	<5	<5	<5	<5	<5
Arsenic (ppb)	<3	<1	7	<2	<1	5	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1 <1	<1	<1	<1	<1	<1	<1
Selenium (ppb)	<1	<1	2	<1.8	<1	3.5	2	<1	2	<1.8	<1	3	<1	<1	2	<1	<1 <1	<1	<1	1.5	<1	<1	<1
Suspended Iron (ppm)	0.01	0.009	0.011	0.012	0.005	0.024	0.022	0.008	0.05	0.005	0.005	0.005	0.009	0.006	0.014	0.008	0 0.007 0.009	0.041	0.009	0.084	0.011	0.009	0.012
Dissolved Iron (ppm)	<0.34	<0.05	1.03	<0.28	<0.05	0.53	0.08	0.07	0.08	0.15	0.05	0.23	<0.05	<0.05	0.06	0.12	0.08 0.15	0.17	0.1	0.25	0.06	<0.05	0.08
Mercury (ppb)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2 <0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

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TABLE 5

WATER CHEMISTRY ANALYSES ATIKOKAN 1988

	SNOW		ICY		ABIE		SLUSH		SOUTH		MARMION NORTH		ANDERSON DAM		MOOSE	
JUNE	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B
TOTAL PHOSPHORUS ppb	13	36	8	28	8	19	<5	23	8	21	9	17	8	31	11	9
SOLUBLE PHOSPHORUS ppb	13	11	8	7	5	12	<5	9	7	9	5	12	7	14	10	6
KJELDAHL NITROGEN ppm	0.33	0.47	0.33	0.4	0.43	0.44	-	0.41	0.33	0.31	0.28	0.32	0.36	0.35	0.31	0.21
NITRATE ppm	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
AUGUST																
TOTAL PHOSPHORUS ppb	10	27	10	66	12	11	6	33	12	13	8	8	11	27	8	9
SOLUBLE PHOSPHORUS ppb	<5	<5	<5	18	<5	<5	<5	<5	<5	<5	<5	<5	<5	10	<5	6
KJELDAHL NITROGEN ppm	0.35	0.47	0.42	0.87	0.37	0.33	0.3	0.45	0.45	0.37	0.35	0.77	0.34	0.37	0.38	0.6
NITRATE ppm	0.02	<0.01	0.02	<0.01	0.01	<0.01	<0.01	<0.01	0.03	0.04	<0.01	<0.01	0.02	0.04	<0.01	<0.01
OCTOBER																
TOTAL PHOSPHORUS ppb	15	11	21	27	19	17	13	12	16	29	16	15	10	16	16	19
SOLUBLE PHOSPHORUS ppb	8	6	6	7	7	7	<5	9	8	8	8	9	10	11	11	13
KJELDAHL NITROGEN ppm	0.24	0.21	0.21	0.17	0.16	0.13	0.11	0.12	0.16	0.1	0.16	0.1	0.19	0.55	0.21	0.14
NITRATE ppm	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

3.2 Comparison Among Years

Despite the conservative nature of the analysis, significant differences among years were generated for many of the parameters tested, particularly those for Snow, Icy and Abie Lakes.

Annual variation of the selected parameters is displayed graphically in Figures 2 to 11. Several parameters appeared to react in a similar fashion in 1987 relative to previous years. Conservative parameters, including hardness, conductivity, alkalinity, calcium, sodium, magnesium, potassium, chloride, soluble silica, dissolved solids and total organic and inorganic carbon, either increased or decreased in Snow, Icy and Abie Lakes during 1987 to more closely resemble levels in Marmion Lake where levels were relatively constant throughout the study. It would appear that these changes are a reflection of mass water movements from Moose and Marmion Lakes into Snow, Icy and Abie Lakes via the Atikokan TGS cooling water system. The results of the analysis of variance (Table 6) and multiple range tests (Tables 7a, b and c) tend to support this conclusion.

Bottom samples in Snow, Icy and Abie Lakes reacted in a similar fashion to that of the surface samples indicating a fair degree of mixing of the station discharge through the water column.

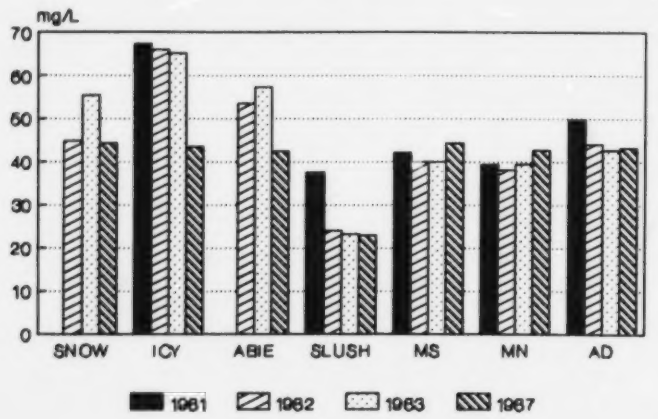
Total phosphorus in surface waters tended to vary substantially among locations in each year up to 1988 (Figure 11) when levels were similar among locations as occurred with the parameters above. The absence of this similarity among locations in 1987 is likely the result of the less consistent operation of the station during 1987 than during 1988. Phosphorus is a relatively dynamic nutrient and likely returns to levels more characteristic of the lake basin when the station is not operating.

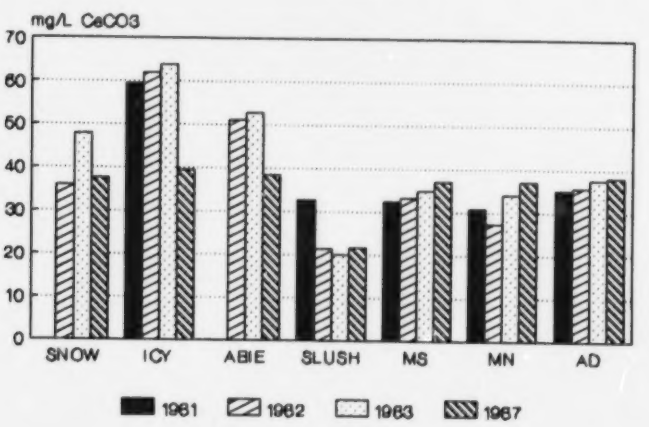
Differences in other parameters among years do not appear to be directly related to station operation. pH levels increased at most locations after 1981 and it appeared that the low 1981 levels may have been the result of analytic error; however, the increase in pH appears to be coincident with a decline in sulphate ion suggesting that the increased pH may not have been the result of analytic error. Among the remaining parameters analyzed, turbidity decreased at most locations in 1987, while Kjeldahl nitrogen was relatively stable among years at all locations with the exception of 1982 when values at all locations were substantially lower than other years.

Nitrate values were on average much lower than in preoperational years; however, the relatively high values were a reflection of occasional values which were an order of magnitude higher than what would normally be expected (Hutchinson 1957). These high values were likely a reflection of analytic error or contamination of the sampling bottles. The low values recorded during the postoperational program are similar to values reported by Maki and Pugh (1984) for lakes in the Atikokan area.

3.3 Commissioning Fluids

Chemicals (boiler-cleaning fluids, for example) used during the commissioning of the station were discharged into the Lower Basin of Moose Lake during 1984 and 1985. The Lower Basin is virtually isolated from the cooling circuit and the Seine River drainage basin. Analysis of water samples collected prior to and during the commissioning period are listed in Table 8.





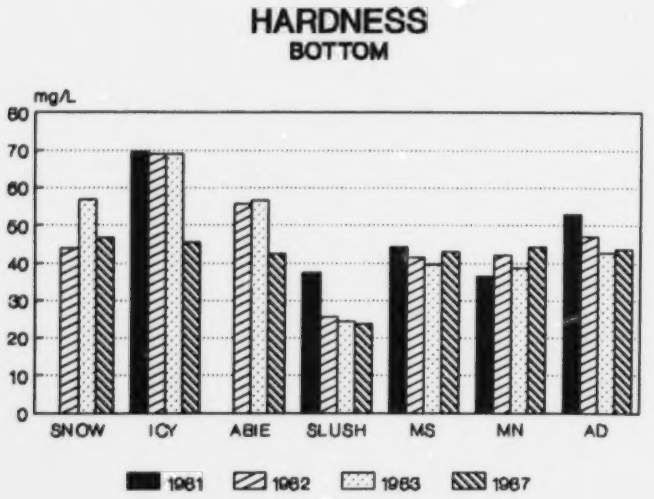
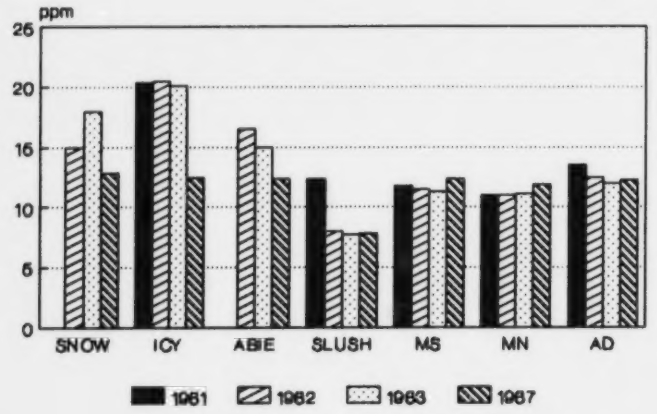
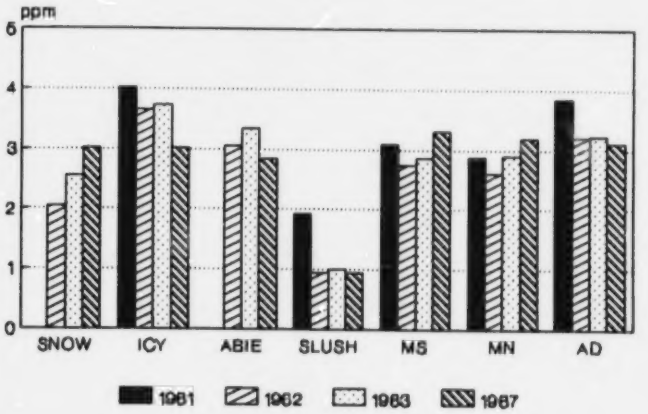
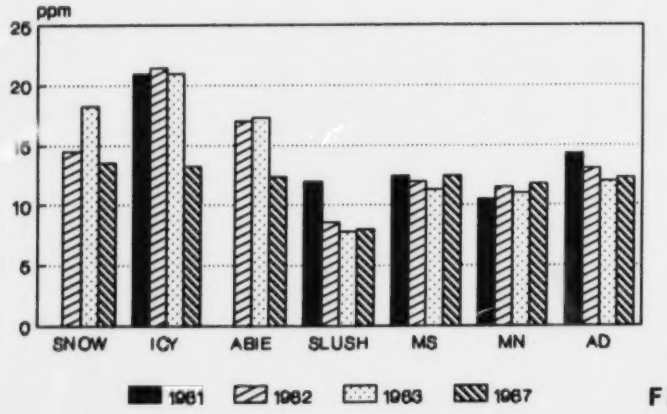


FIGURE 2
ANNUAL VARIATION IN HARDNESS AND ALKALINITY

MS-MARMION SOUTH
MN-MARMION NORTH
AD-ANDERSON DAM







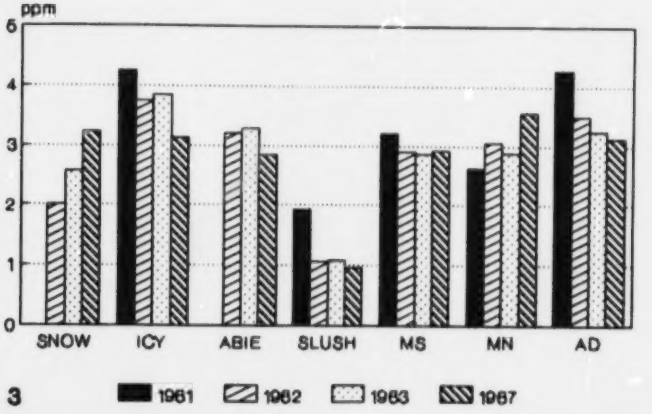
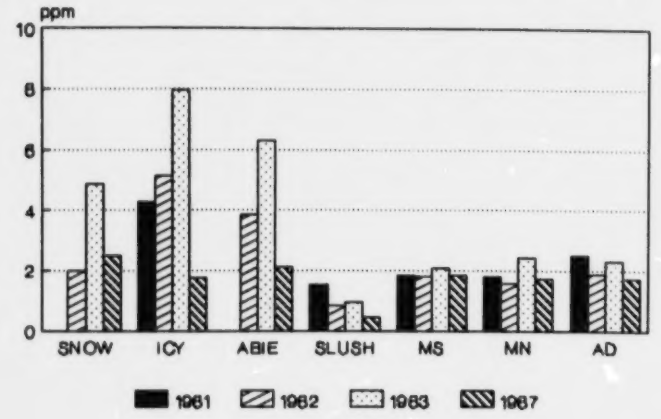
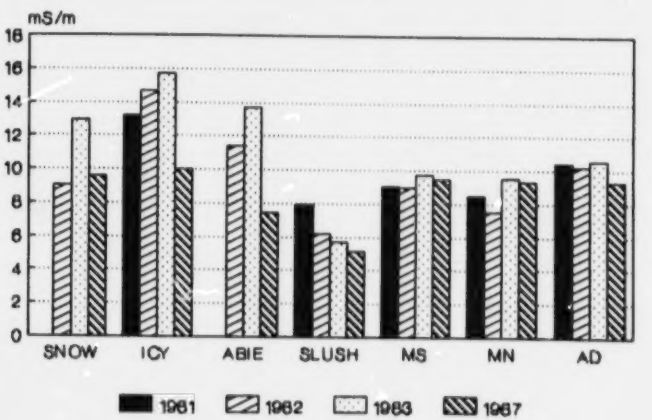
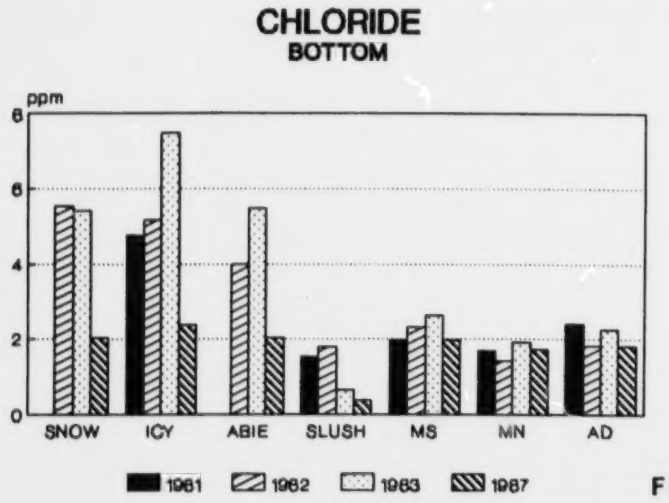


FIGURE 3

ANNUAL VARIATION IN CALCIUM AND MAGNESIUM







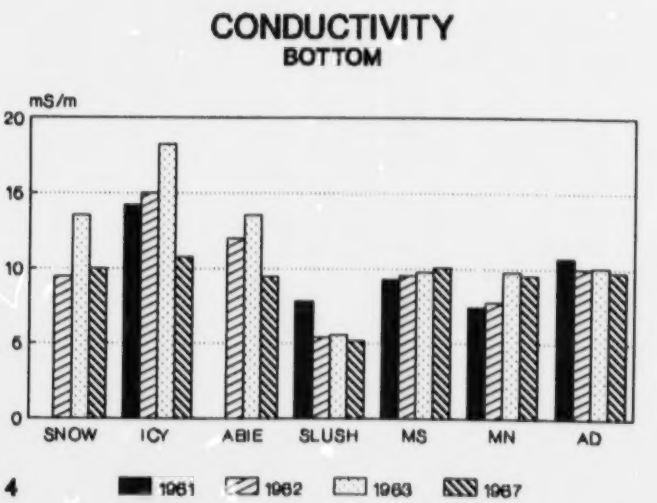


FIGURE 4

ANNUAL VARIATION IN CHLORIDE AND CONDUCTIVITY

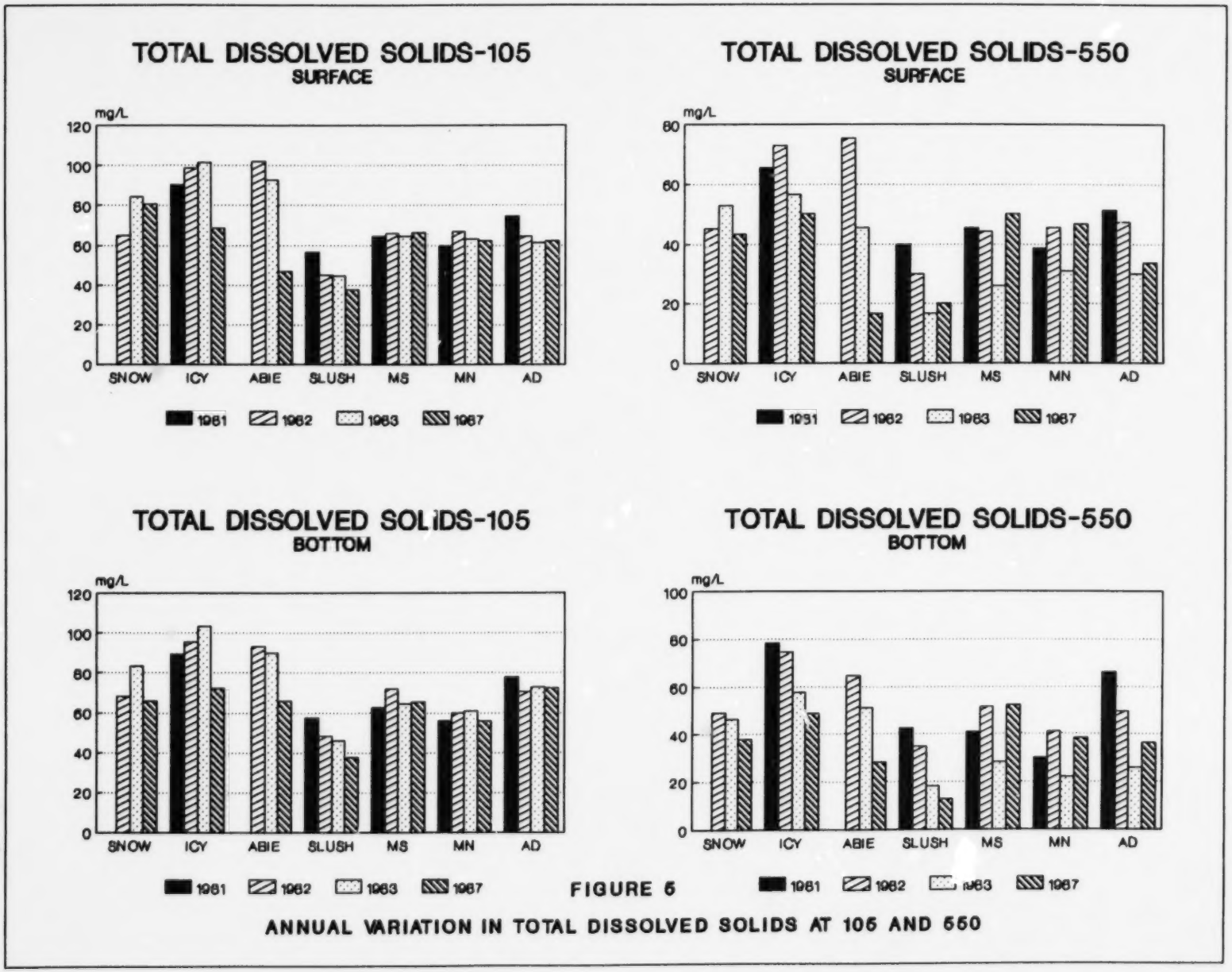
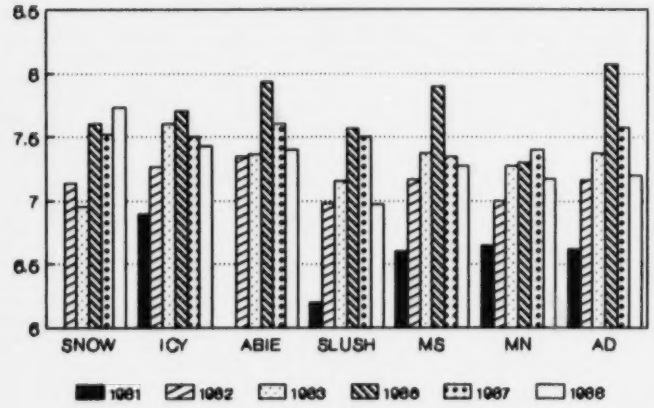
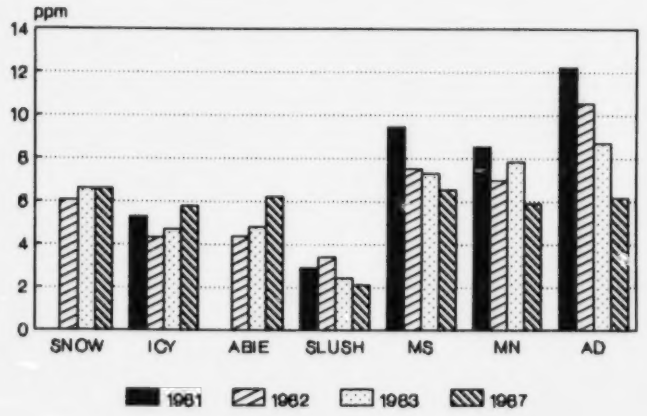
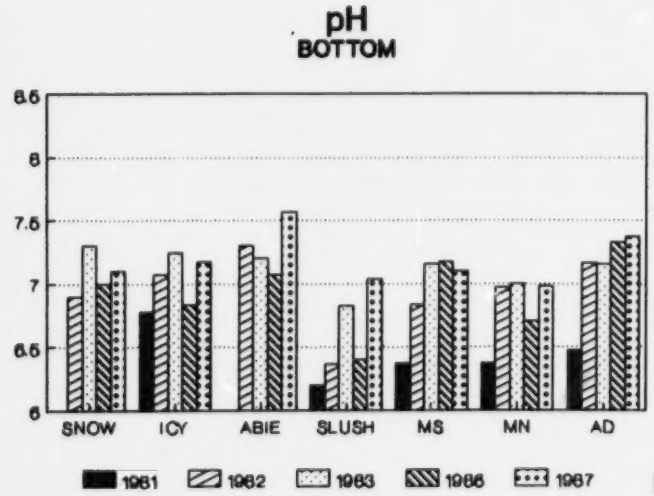


FIGURE 6

ANNUAL VARIATION IN TOTAL DISSOLVED SOLIDS AT 105 AND 550







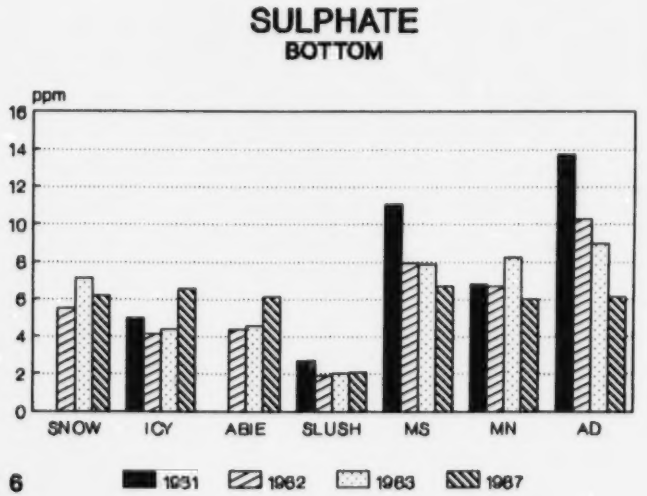
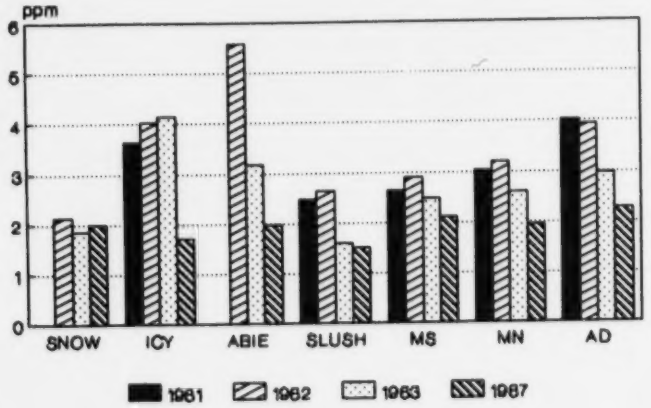
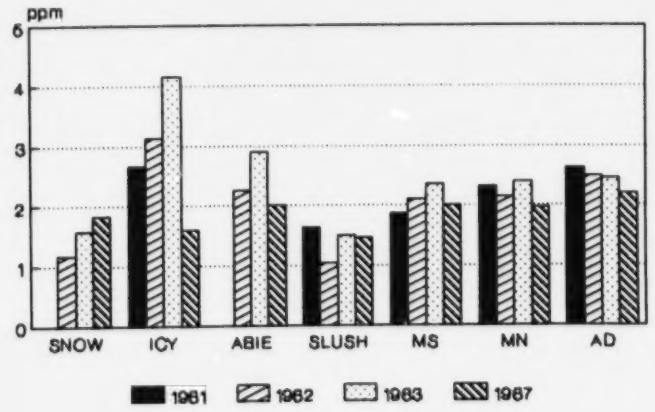
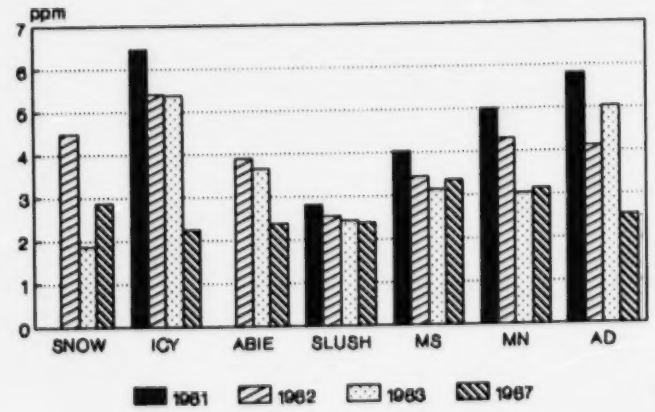


FIGURE 6

ANNUAL VARIATION IN pH AND SULPHATE







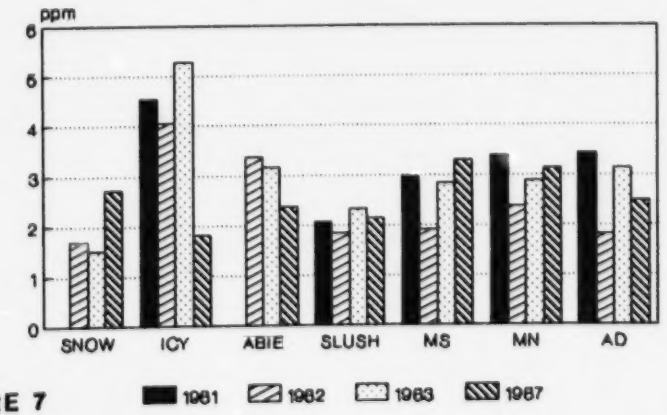
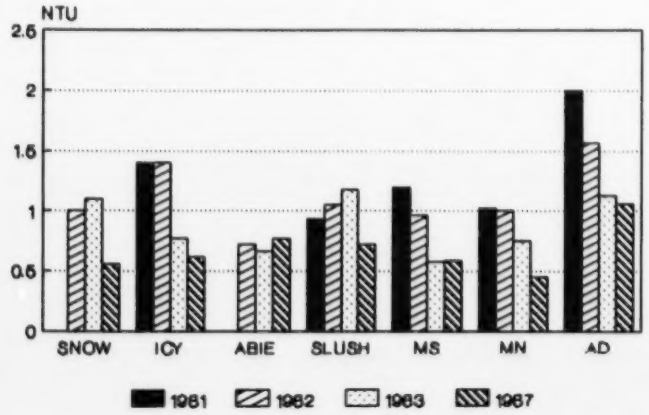
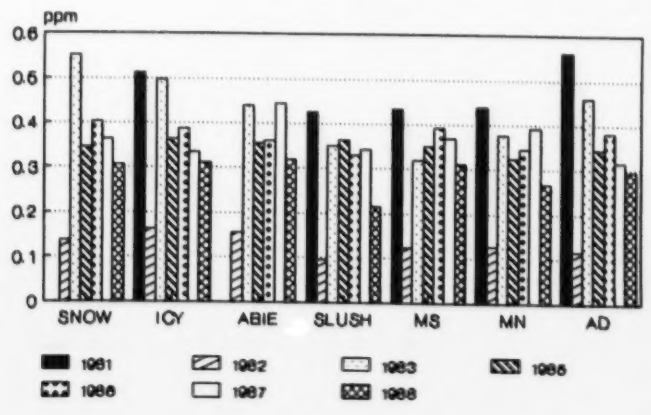
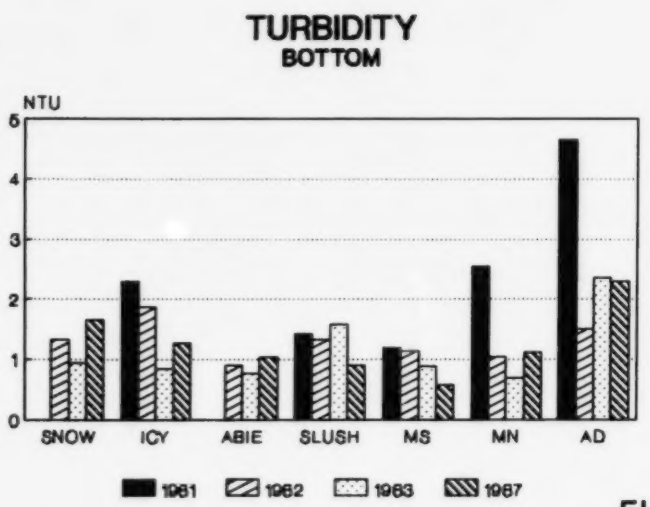


FIGURE 7

ANNUAL VARIATION IN TOTAL AND SOLUBLE SILICA







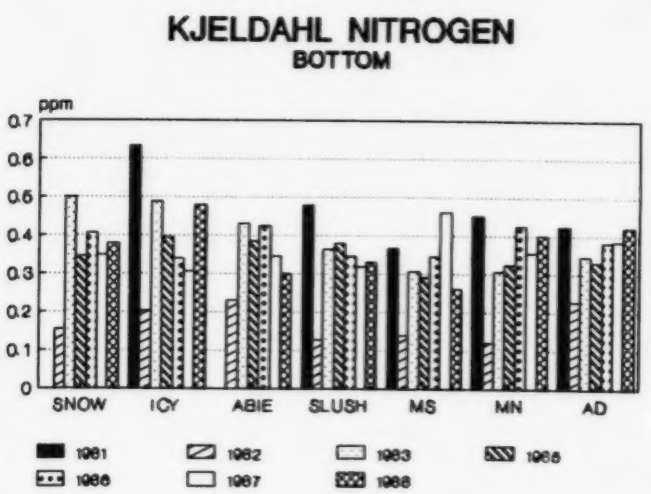


FIGURE 8
ANNUAL VARIATION IN TURBIDITY AND TOTAL KJELDAHL NITROGEN

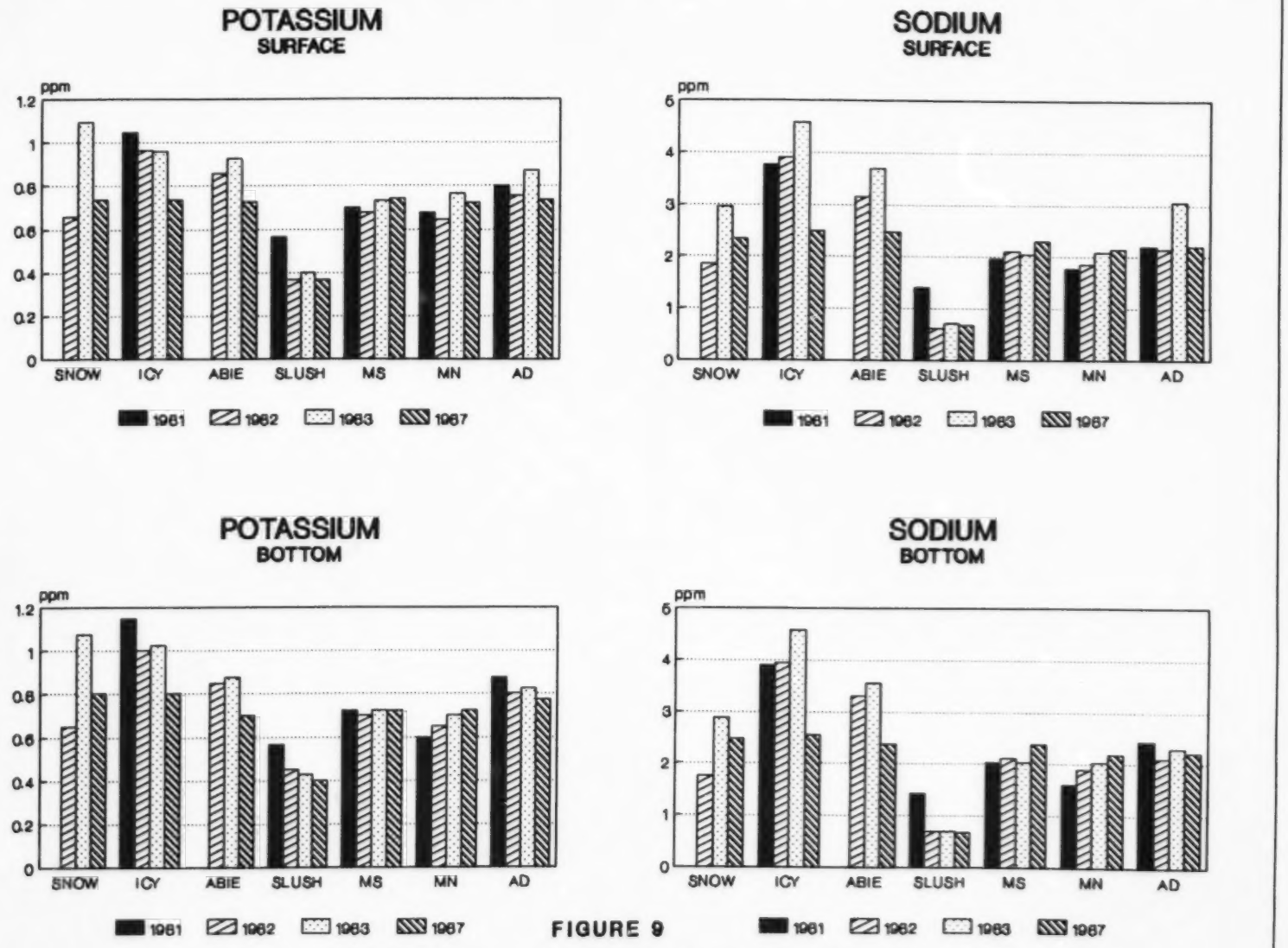
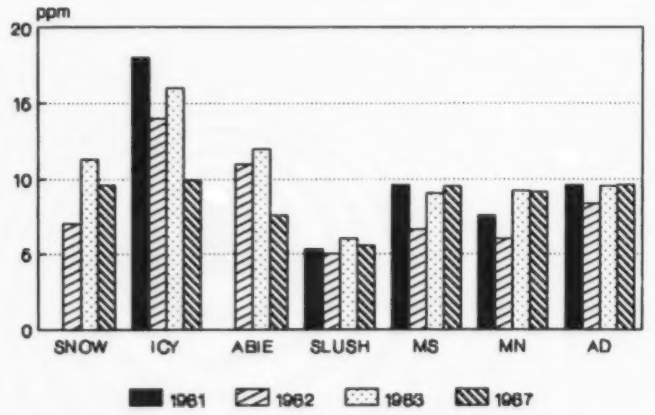
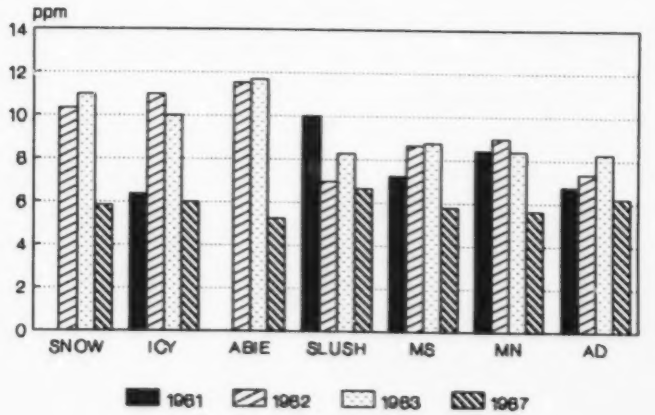
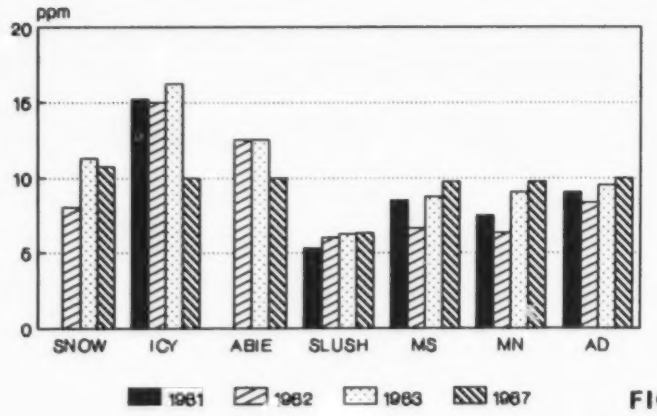


FIGURE 9

ANNUAL VARIATION IN POTASSIUM AND SODIUM







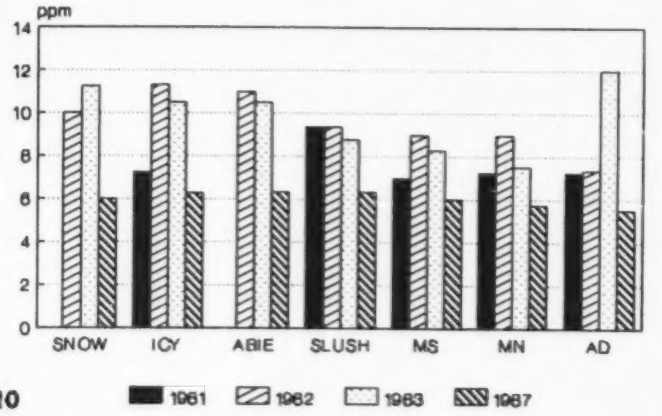
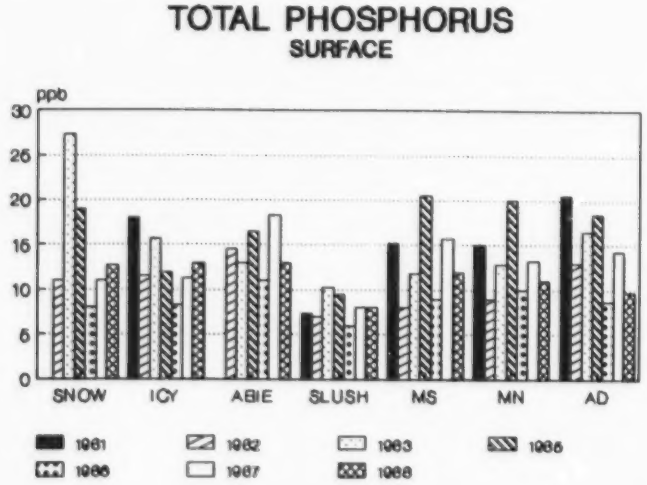
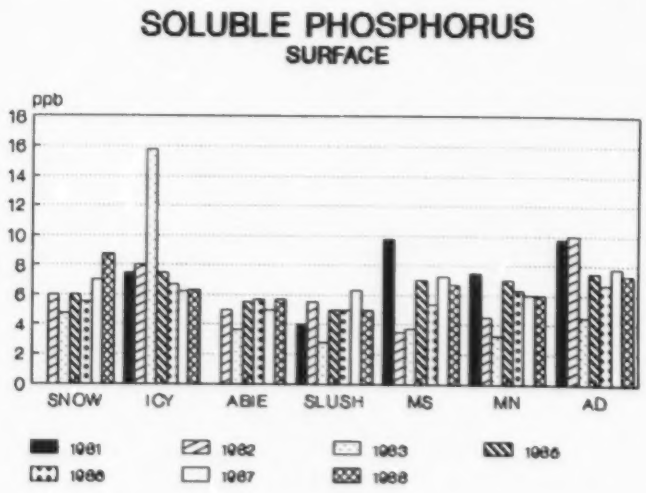
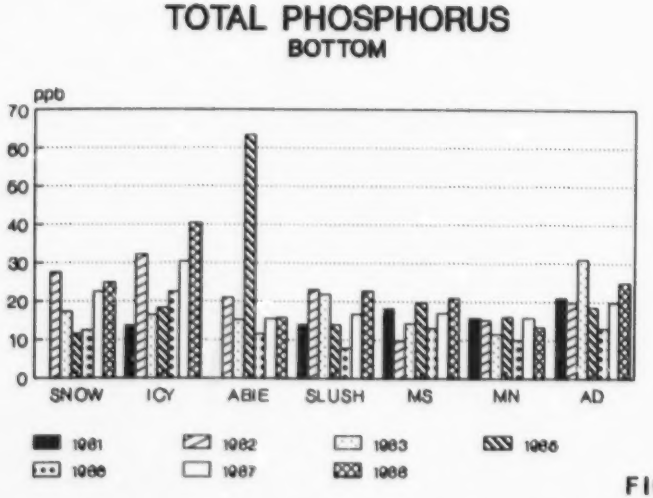


FIGURE 10

ANNUAL VARIATION IN TOTAL INORGANIC AND ORGANIC CARBON







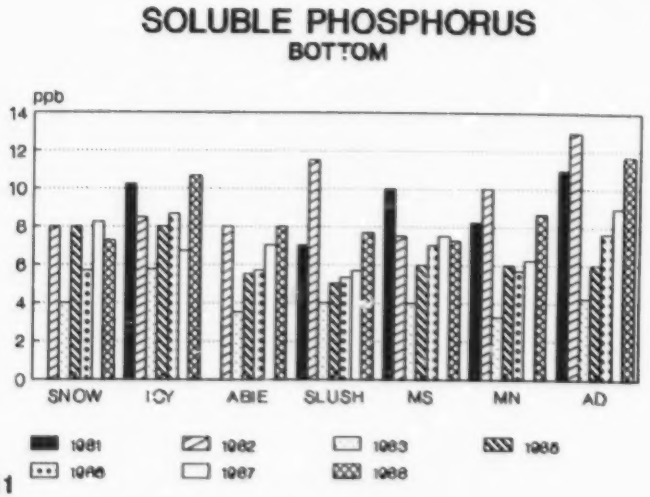


FIGURE 11

ANNUAL VARIATION IN TOTAL AND SOLUBLE PHOSPHORUS

TABLE 6

PROBABILITY OF DIFFERENCES AMONG YEARS FROM ONE-WAY ANALYSIS OF VARIANCE FOR SELECTED CHEMICAL PARAMETERS IN SURFACE AND BOTTOM SAMPLES-ATIKOKAN 1981-88

	SNOW		ICY		ABIE		SLUSH		MARMION SOUTH		MARMION NORTH		ANDERSON DAM	
	SURF	BTM	SURF	BTM	SURF	BTM	SURF	BTM	SURF	BTM	SURF	BTM	SURF	BTM
Hardness	NS	NS	0.001	0.001	0.01	0.01	NS	NS	NS	NS	NS	NS	NS	NS
Alkalinity	0.01	-	0.001	-	0.001	-	NS	-	NS	-	0.01	-	NS	-
Conductivity	0.01	0.05	0.001	0.01	0.05	0.01	NS	NS	NS	NS	NS	NS	NS	NS
Calcium	0.05	0.05	0.001	0.001	NS	0.01	NS	NS	NS	NS	NS	NS	NS	NS
Magnesium	0.05	0.05	0.05	0.001	NS	NS	NS	NS	NS	0.05	NS	NS	NS	NS
Sodium	0.05	NS	0.05	0.001	0.05	0.05	NS	NS	NS	NS	0.05	0.01	NS	NS
Potassium	0.01	0.05	0.05	0.001	NS	0.01	NS	NS	NS	NS	NS	NS	NS	NS
Chloride	0.05	NS	0.001	0.001	0.05	0.01	NS	NS	NS	NS	NS	NS	NS	NS
Tot Inorg Carbon	0.01	NS	0.01	NS	NS	NS	NS	NS	0.05	NS	0.01	0.01	NS	NS
Tot Org Carbon	0.01	0.05	NS	NS	0.05	0.01	NS	NS	0.05	0.05	0.05	NS	NS	NS
Dis Solids-105	NS	NS	0.01	0.01	0.05	0.001	NS	NS	NS	NS	NS	NS	NS	NS
Dis Solids-550	NS	NS	NS	0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.05
Tot Silica	NS	NS	0.05	0.01	NS	NS	NS	NS	NS	NS	0.01	NS	0.05	0.05
Sol Silica	NS	0.05	0.05	0.001	NS	0.05	NS	NS	NS	NS	NS	NS	NS	NS
Turbidity	NS	NS	0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Kjeldahl Nitrogen	0.05	0.05	0.001	NS	NS	NS	0.05	NS	0.05	0.05	NS	NS	NS	NS
Tot Phosphorus	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sol Phosphorus	-	NS	-	NS	-	NS	-	NS	-	NS	-	NS	-	NS
Sulphate	NS	NS	NS	0.01	0.01	0.01	NS	NS	0.01	0.01	0.05	0.05	0.001	0.001
pH	0.05	NS	NS	NS	NS	NS	0.05	NS	0.05	NS	NS	NS	0.05	NS

NS-not significant

TABLE 7a

RESULTS OF DUNCAN'S MULTIPLE RANGE TESTS
Means and Years which are Not Significantly
Different (·····) are Presented

CONDUCTIVITY

	1987	1981	1982	1983
			·····	
IC-S	10	13.3	14.7	15.7
AB-B	9.4		12	13.5

	1987	1981	1982	1983
			····	····
IC-B	10.7	14.3	15	18.3

	1987	1982	1983
	·····	····	
SN-S	9.6	9.1	12.9
SN-B	10	9.4	13.5

	1987	1982	1983
	·····		
		·····	
AB-S	7.5	11.4	13.7

ALKALINITY

	1987	1981	1982	1983
IC-S	40	60	62	64

	1987	1982	1983
AB-S	38	51	53

	1987	1982	1983
	·····	····	
SN-S	38	36	48

	1987	1983	1981	1982
	·····			
		·····		
			·····	
MN-S	37	34	31	27

TOTAL ORGANIC CARBON

	1987	1981	1982	1983
SN-S	5.8		10.3	11
SN-B	6		10	11.3
AB-S	5.2		11.5	11.7
AB-B	6.3		11	10.5
MN-S	5.6	8.4	9	7.8

	1987	1981	1982	1983
	·····			
		·····		
MS-S	5.8	7.2	8.7	8.8
MS-B	6	7	9	8.3

CHLORIDE

	1987	1981	1982	1983
IC-S	1.76	4.28	5.13	7.98
IC-B	2.38	4.75	5.17	7.5
AB-B	2.03		4	5.48

	1987	1982	1983
	·····	····	
SW-S	2.5	2	4.85

	1987	1982	1983
	·····		
		·····	
AB-S	2.1	3.85	6.03

TOTAL SILICA

	1987	1981	1982	1983
IC-S	1.7	3.7	4	4.2
IC-B	2.3	6.5	5.4	5.4

	1987	1983	1982	1981
	·····			
		·····		
MN-S	2	2.6	3.2	3
AD-S	2.3	3	3.9	4

	1987	1982	1983	1981
	·····			
		·····		
AD-B	2.5	4.1	5	5.8

SOLUBLE SILICA

	1987	1981	1982	1983
IC-B	1.8	4.6	4.1	5.3
AB-B	2.4		3.4	3.2

	1987	1981	1982	1983
	·····			
		·····		
SN-B	2.7		1.7	1.5
IC-S	1.6	2.7	3.1	4.2

CALCIUM

	1987	1981	1982	1983
IC-S	13	20	21	20
IC-B	13	21	22	21
AB-B	12		17	17

	1987	1982	1983
	·····		
		·····	
SN-S	13	15	18
SN-B	14	15	18

TOTAL DISSOLVED SOLIDS-5

	1987	1983	1982	1981
	·····			
		·····		
			·····	
IC-B	49	58	75	79

	1987	1983	1982	1981
	·····			
		·····		
			·····	
AD-B	36	26	49	66

SN-Snow L. IC-Icy L. AB-Abie L. SL-Slush L. MS-Marmion South MN-Marmion North AD-Anderson Dam
S-surface B-bottom

TABLE 7b

RESULTS OF DUNCAN'S MULTIPLE RANGE TESTS
Means and Years which are Not Significantly
Different (-----) are Presented

MAGNESIUM

	1987	1982	1983	1981
IC-B	3.13	3.75	3.85	4.25
IC-S	3.01	3.65	3.73	4.03
SN-S	3.02	2.55	2.05	
SN-B	3.23	2.58	2	
MS-B	2.85	2.93	2.9	3.2

	1983	1987	1982	1981

pH

	1981	1982	1988	1983	1987	1986
AD-S	6.6	7.2	7.2	7.4	7.6	8.1
SL-S	6.2	7	7	7.2	7.5	7.6
MS-S	6.6	7.3	7.2	7.4	7.4	7.9

	1983	1982	1987	1986	1988

	1981	1982	1983	1987	1986
SN-S	7	7.1	7.5	7.6	7.7

TOTAL INORGANIC CARBON

	1987	1982	1983	1981
IC-S	9.9	14	16	18.1

	1982	1983	1987	1981
MS-S	6.67	9	9.5	9.6

	1982	1981	1987	1983
MN-S	6	7.6	9.2	9.3

	1982	1987	1983
SN-S	7	9.6	11.3

	1982	1981	1983	1987
MN-B	6.3	7.3	9	9.8

POTASSIUM

	1987	1983	1982
IC-B	0.8	1.03	1

	1987	1981	1982
IC-S	0.74	1.05	0.97
AB-B	0.7		0.85

	1987	1982	1983
SN-S	0.74	0.66	1.1

	1982	1987	1983

	1982	1981	1983	1987
SN-B	0.65	0.8	1.1	

TURBIDITY

	1987	1983	1982	1981
IC-S	0.62	0.78	1.4	1.4

HARDNESS

	1987	1981	1982	1983
IC-S	44	67	66	65
IC-B	46	70	69	69
AB-S	42		54	57
AB-B	42		56	57

TOTAL DISSOLVED SOLIDS-105

	1987	1981	1982	1983
IC-S	69	91	99	102
IC-B	72	90	96	104
AB-S	47		102	93
AB-B	66		93	90

S-Snow L. IC-Icy L. AB-Abie L. SL-Slush L. MS-Harmion South MN-Harmion North AD-Anderson Dam
S-surface B-bottom

TABLE 7c

RESULTS OF DUNCAN'S MULTIPLE RANGE TESTS
Means and Years which are Not Significantly
Different (-----) are Presented

SULPHATE

	1987	1981	1982	1983
IC-B	6.6	5	4.4	4.1
AB-S	6.2		4.4	4.8
AB-B	6.1		4.4	4.6

	1987	1983	1982	1981
AD-S	6.18	8.7	10.5	12.3

	1987	1982	1983	1981
MN-S	5.88	7	7.83	8.55

	1987	1983	1982	1981
MS-S	6.56	7.33	7.5	9.45
MS-B	6.7	7.88	7.9	11.1

	1987	1982	1981	1983
MN-B	5.98	6.67	7.5	8.2

	1987	1983	1982	1981
AD-B	6.13	8.95	10.2	13.8

SODIUM

	1987	1981	1982	1983
IC-B	2.6	3.9	4	4.6

	1987	1981	1982	1983
IC-S	2.5	3.7	3.9	4.6
AB-B	2.4		3.3	3.6

	1987	1982	1983
AB-S	2.5	3.2	3.7

	1987	1983	1982	1981
MN-S	2.2	2	1.9	1.8

	1987	1983	1982	1981
MN-B	2.2	2	1.9	1.6

	1982	1987	1983
SN-S	1.9	2.3	3

TOTAL KJELDAHL NITROGEN

	1982	1988	1983	1985	1987	1986	1981
MS-S	0.12	0.31	0.32	0.35	0.37	0.39	0.44

	1982	1988	1986	1987	1983	1985	1981
SL-S	0.1	0.21	0.33	0.34	0.35	0.37	0.43

	1982	1988	1985	1987	1986	1983
SN-S	0.14	0.31	0.35	0.37	0.4	0.55

	1982	1985	1987	1988	1986	1983
SN-B	0.15	0.35	0.35	0.38	0.41	0.5

	1982	1988	1987	1985	1986	1983	1981
IC-S	0.16	0.31	0.34	0.37	0.39	0.5	0.51

	1982	1988	1985	1983	1986	1981	1987
MS-B	0.14	0.26	0.29	0.31	0.35	0.37	0.46

SN-Snow L. IC-Icy L. AB-Abie L. SL-Slush L. MS-Marmion Sc MN-Marmion North AD-Anderson Dam
S-surface B-bottom

TABLE 8

CHEMICAL ANALYSIS OF THE LOWER BASIN OF MOOSE LAKE

PARAMETER	LOCATION	JAN 1984	MAY 1985	AUG 1985	OCT 1985
pH	1		7.1		7.0
	2	7.5	7.4		
	3	7.1	7.4		7.2
	4	7.1	7.4		
	5	7.1	7.4		7.3
	MEAN	7.2	7.4		7.2
TOTAL	1		3		
SUSPENDED	2	<2	7		
SOLIDS	3	3	<2		
	4	<2	<2		
	5	<2	<2		
	MEAN	<2	<3		
SUSPENDED	1				0.083
IRON	3				0.051
	5				0.039
	MEAN				0.058
DISSOLVED	1				1.36
IRON	3				0.18
	5				0.18
	MEAN				0.57
TOTAL	1		5.18		1.44
IRON	2	0.77	0.36		
	3	0.5	0.35		0.23
	4	0.39	0.18		
	5	0.4	0.17		0.22
	MEAN	0.52	0.27		0.63
COPPER	1		0.005	<0.001	<0.001
	2	0.002	0.007		
	3	0.003	0.006	<0.001	<0.001
	4	0.003	0.005		
	5	0.003	0.005	<0.001	<0.001
	MEAN	0.003	0.006	<0.001	<0.001
NICKEL	1		<0.005	<0.005	0.006
	2	<0.005	<0.005		
	3	<0.005	<0.005	<0.005	0.006
	4	<0.005	<0.005		
	5	<0.005	<0.005	<0.005	0.006
	MEAN	<0.005	<0.005	<0.005	0.006

PARAMETER	LOCATION	JAN 1984	MAY 1985
BOD	1		<1
	2	1	<1
	3	1	<1
	4	2	<1
	5	1	<1
	MEAN	1	<1
COD	1		<5
	2	<5	<5
	3	<5	<5
	4	<5	<5
	5	<5	8
	MEAN	<5	<6
TOTAL	1		0.048
PHOSPHORUS	2	0.011	0.016
	3	0.110	0.015
	4	0.074	0.011
	5	0.065	0.034
	MEAN	0.065	0.019
SOLUBLE	1		0.009
PHOSPHORUS	2	0.005	0.009
	3	0.051	0.008
	4	0.035	0.007
	5	0.026	0.026
	MEAN	0.029	0.013
CITRIC	1		<1
ACID	2	<1	<1
	3	<1	<1
	4	<1	<1
	5	<1	<1
	MEAN	<1	<1
AMMONIA	1		<0.01
	2	0.11	0.07
	3	0.31	0.03
	4	0.29	0.02
	5	0.30	<0.01
	MEAN	0.25	<0.03

Notes: Location 1 is at the discharge stream
Locations 2-5 are along a transect
from the stream to the centre
of the Basin
Measurements are in ppm

Of the parameters measured, several demonstrated a trend of higher levels at the point of discharge (location 1) during the commissioning phase. These parameters were total suspended solids, suspended, dissolved and total iron and total phosphorus. With the exception of suspended and dissolved iron, levels of each of these parameters became similar to or fell below pre-discharge levels as distance from the point of discharge increased.

Copper levels at each sampling location in May, 1985 were above pre-dumping levels (January, 1984); however, levels measured after May, 1985 were below levels measured before dumping.

Nickel was the only parameter which was measured at higher levels on the last sampling date (0.006 ppm, October, 1985) relative to pre-dumping measurements (less than 0.005 ppm).

4.0 DISCUSSION

4.1 Exceedances of Water Quality Guidelines

A list of chemical measurements which exceeded the Ministry of Environment water quality objectives (Ontario Ministry of the Environment 1984) are listed in Table 9. Generally, the number of exceedances measured in 1987 was below that of preoperational years. The lone exception to this generality was iron; however, all but two of the exceedances for 1987 were recorded for samples collected during August when the limit of detection was substantially higher than in the samples collected during the other months. This suggests that the analyses may be less reliable.

Exceedances of the aluminum guideline only occurred in 1981; however, the analytical level of a detection of aluminum increased after 1981. Consequently, some exceedances may have occurred since 1981 but were masked by the higher level of detection.

4.2 Evaluation of Hypotheses

The primary effect of the operation of the Atikokan TGS on water quality was to make the cooling water system more homogeneous. This was primarily due to relocation of water from Moose and Marmion Lakes into the three small lakes of the circuit through the condenser-cooling-water system. This relocation effect has been identified previously at Lennox TGS (Dunstall et. al. 1985) and Nanticoke TGS (Dunstall et. al. 1989).

During a workshop involving representatives from the Ministries of Natural Resources and Environment and from Ontario Hydro (Greig et. al. 1984) a number of hypotheses of effect were developed. These hypotheses consist of a series of linkages from an action associated with operation or construction of the station to an eventual effect on a valued ecosystem component. Several of these hypotheses refer to effects on water quality. These hypothesized effects will be discussed here. The reader is referred to Greig et. al. (1984) for a full description of the hypotheses.

Hypothesis No. 7

Hypothesis 7 deals with the possible effect of discharges of sewage and cooling water on the distribution, composition, abundance and growth of fish. The hypothesis has a number of intermediate linkages dealing with water chemistry.

Link 1: "Discharges from sewage lagoons will result in increased BOD and phosphorus."

Relatively large discharges of sewage into Snow Lake occurred when the construction camp was

TABLE 9

EXCEEDANCES OF MINISTRY OF ENVIRONMENT
WATER QUALITY OBJECTIVES

PARAMETER	OBJECTIVE	YEAR	LOCATION		NUMBER	MAX/MIN RECORDED
pH	6.5-8.5	1981	ICY	-S	1	6.4
				-B	1	6.2
			SLUSH	-S	1	5.6
				-B	1	5.5
			MS	-S	1	6.1
				-B	1	5.9
			MN	-S	1	6.0
				-B	1	5.8
			AD	-S	1	6.0
				-B	1	6.1
			LS	-S	1	5.8
				-B	2	5.7
		1982	SLUSH	-B	2	6.1
			MS	-B	1	6.4
			LS	-B	1	6.4
TOTAL PHOSPHORUS (SURFACE)	20 ppb	1981	ICY	-S	1	36
			MN	-S	1	21
			AD	-S	1	47
		1983	SNOW	-S	1	45
			ICY	-S	1	27
		1987	ABIE	-S	1	23
			AD	-S	1	27
ALUMINUM	0.1 ppm	1981	ICY	-S	1	0.20
			SLUSH	-B	1	0.23
			MS	-B	1	0.96
			MN	-S	1	1.4
				-B	2	0.93
			AD	-S	2	1.0
				-B	2	1.2
			LS	-S	1	0.18
				-B	1	0.15
COPPER	5 ppb	1981	MN	-S	1	6
		1982	SNOW	-S	1	45
			ICY	-S	1	9
				-B	1	20
			ABIE	-B	1	6
			MN	-S	1	10
				-B	1	6
		1987	MN	-S	1	12
			AD	-B	1	12
			MOOSE	-S	1	9
IRON	0.3 ppm	1981	ICY	-B	1	1.36
			MN	-B	1	1.03
			AD	-B	1	0.85
		1982	SNOW	-S	1	0.31
				-B	1	0.35
			ICY	-S	1	0.32
				-B	2	0.51
			SLUSH	-B	1	0.46
			AD	-S	1	0.37
				-B	1	0.39
		1983	SLUSH	-B	2	0.47
			AD	-B	1	3.70
		1987	SNOW	-S	1	1.08
				-B	1	3.53
			ICY	-S	1	1.05
				-B	2	9.39
			SLUSH	-S	1	1
			AD	-S	1	2.61
				-B	2	9.19
			MOOSE	-B	1	2.58

active. These discharges resulted in increases in total phosphorus, total Kjeldahl nitrogen and BOD in the area of the immediate sewage discharge stream but had minimal impact on open water concentrations (Haymes 1985b). Since 1984 the construction camp has been removed and the production of sewage has been greatly reduced to levels which do not exceed the capacity of the lagoons as predicted in Kwong and Fung 1982.

Statistical analysis of chemical data indicate that increases in the concentration of nutrients has not occurred during the postoperational phase of the study (Table 6). In addition, when the station is continually operating, levels of most nutrients are similar among all of the cooling circuit lakes. Consequently, although there may be some loading of nutrients to the system from the sewage lagoon or from certain process systems at the station (eg. boiler blowdown, Reeves and Nguyen 1988), they are not reflected in open water concentrations.

Link 5: "Cooling water discharges will result in increased suspended and dissolved solids and altered pH."

Total suspended solids measurements were not appropriate for rigorous statistical analysis; however, statistical differences were apparent for total dissolved solids (Table 6). Although the hypothesis suggested that dissolved solids would increase as a result of cooling water discharge, the only significant differences occurred in Icy and Abie Lakes where the 1987 results were significantly lower than the preoperational levels (Table 7). This suggests that the link is invalid in its present form. The decrease in dissolved solids in the small lakes, however, may have some biological implications which will be discussed in subsequent reports.

pH values which were relatively low in 1981 increased substantially in 1982 and subsequently remained relatively constant (Figure 8). The substantial increase in pH in the study area several years prior to station operation indicates that although pH has changed over the study period, this change was not related to operation of the station. Consequently, the link appears to be invalid for pH as well.

Link 13: "Resuspension of sediments as a result of increased current will increase nutrients and turbidity."

As noted above, significant increases in nutrients among years, which could be attributed to station operation were not detected. Changes in nutrients, as in other parameters, were a reflection of mass water movements into the first three lakes of the cooling circuit from Marmion and Moose Lakes. This was particularly obvious in 1988 when the station was more consistently operating. The lack of increase in nutrients does not necessarily indicate that production has not increased as flushing rates due to increased currents must also be taken into account.

Significant differences in turbidity were only detected in Icy Lake surface samples where 1987 levels tended to be lower than during the preoperational years (Table 7). Consequently, although station operation may have resulted in decreased turbidity in Icy Lake, the premise that resuspended sediments would increase nutrient concentrations and turbidity is not valid.

Link 15: "Resuspension of sediments will increase the availability of metals for uptake by biota."

Most of the heavy metals analyzed were below the limit of detection in the majority of preoperational and postoperational water samples. Exceptions to this generality resulted in some exceedances of MOE objectives (Table 9). The three metals which were recorded at levels above the guidelines were aluminum, copper and iron. Exceedances of aluminum were recorded in 1981 only, but subsequent exceedances may have been masked by a higher level of detection. The number of exceedances of the copper objective in 1987 (3) was consistent with the number of

exceedances recorded in 1981 to 1983 (0-6). The frequency of exceedances of the iron objective was highest in 1987 (10) relative to 1981-1983 (3-8).

Based on the frequency of exceedances of water quality objectives, this link cannot be completely ruled out, particularly with respect to iron which is prevalent throughout the system due to the historic iron mining activities in the area.

Hypothesis No. 8

Hypothesis 8 deals with the effects of boiler cleaning waste discharges and coal pile run-off on the water quality of the Lower Basin of Moose Lake. The Lower Basin is completely isolated from the cooling circuit and provides staging and nesting habitat for waterfowl.

Link 1: "Discharges of boiler cleaning wastes will lead to changes in water quality of the Lower Basin of Moose Lake."

Several water quality parameters measured in the Lower Basin after discharge were highest at the point of discharge; however, away from the point of discharge each of these parameters was similar to or below corresponding measurements made prior to waste discharge (Table 8). Only nickel was measured at levels above pre-discharge levels (away from the point of discharge) on the last sampling date (October, 1985).

Most of the parameters measured in the Lower Basin, away from the point of discharge, were similar to values measured in the cooling water lakes during 1987. The two exceptions were iron which was higher in the Lower Basin prior to and during discharge and nickel which was higher in the Lower Basin on the last sampling date only. Thus the elevated levels of iron in the Lower Basin were not solely the result of the discharge of commissioning fluids. The slightly higher levels of nickel in October, 1985 may be the result of the discharges.

Hypothesis No. 9

Hypothesis 9 deals with the effects of ash pile leachate on the water quality of Snow and Icy Lakes and the levels of metals in fish.

Link 6: "Groundwater contaminated by leachate from the ash pile may seep into Snow and Icy Lakes leading to increased metal and dissolved solids concentrations and increased pH."

As noted above (Hypothesis 7, Link 15), iron was the only metal for which the number of exceedances of MOE objectives appeared to increase. However, these exceedances occurred throughout the cooling circuit and thus were not likely the result of ash pile leachate.

Changes in total dissolved solids in Snow (increase) and Icy (decrease) Lakes were attributed to relocation of water from Moose and Marmion Lakes and not to ash pile leachate.

pH increased in all of the basins of the cooling water circuit over the length of the study. This was considered a general phenomenon and unrelated to construction or operation of the station.

5.0 CONCLUSIONS

1. Changes in many chemical parameters in Snow, Icy and Abie Lakes can be attributed to relocation of water from Marmion and Moose Lakes by way of the condenser cooling water system.

2. Nutrient levels in the cooling water circuit were quite variable among years and locations. In 1988, however, when the station was more consistently operating, the levels of nutrients were very consistent among the sampling locations reflecting the relocation of water by the CCW system.

3. Most of the hypotheses which involved water quality changes were generally considered false, primarily due to the influence of water relocation on the chemistry of Snow, Icy and Abie Lakes.

4. pH levels increased after 1981, but this appeared to be a general phenomenon unrelated to station operation or construction.

5. Most heavy metal measurements in water were below provincial water quality objectives. Only the exceedances of the iron objective appeared to increase after operation of the station.

6. Most parameters measured in the Lower Basin of Moose Lake were relatively high at the point of commissioning fluids discharge. Levels of these parameters, however, declined rapidly and were similar to or below pre-discharge values at increasing distances from the discharge stream. Nickel was the only parameter which exceeded pre-discharge values away from the discharge stream. Consequently, although there were some loadings of contaminants into the Lower Basin, these loadings did not increase the levels of most parameters in the main basin.

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APPENDIX 1

RESULTS OF WATER CHEMISTRY ANALYSES
ATIKOKAN 1987-MARCH 1988

SNOW LAKE	MAY		AUGUST		OCTOBER		MARCH	
	SURFACE	BOTTOM	SURFACE	BOTTOM	SURFACE	BOTTOM	SURFACE	BOTTOM
pH	7.4	6.7	7.7	6.8	7.7	7.6	7.3	7.3
Conductivity (mS/m)	8.46	9	9.7	11	10.3	10.2	9.9	10
Tot Alkalinity (mg/L-CaCO3)	35.66	40.08	38		36		41	
Turbidity (NTU)	0.8	1.4	0.57	4.5	0.7	0.54	0.15	0.17
TSS @105 (mg/L)	<1	7	3.6	9.6	3.6	2	0.8	2.4
TSS @550 (mg/L)			2.8	6.4	<2	2	<0.4	1.6
TDS @105 (mg/L)	138	70	62	74	67	61	56	58
TDS @550 (mg/L)			28	30	50	43	52	40
Total Phosphorus (ppb)	6	23	16	37	17	18	5	11
Soluble Phosphorus (ppb)	<5	7	<5	5	13	16	<5	5
Kjeldahl Nitrogen (ppm)	0.52	0.61	0.23	0.26	0.4	0.3	0.31	0.22
Nitrite (ppm-NO2)	<0.01	0.01	0.04	0.08	<0.01	0.01	<0.01	0.01
Nitrate (ppm-NO3)	0.01	0.01	0.03	0.06	0.02	0.02	0.09	0.06
Ammonia (ppb)	40	70	<10	30	70	31	<10	10
Total Silica (ppm)	2.75	4.25	1.2	2.6	2.1	2.35	1.92	2.23
Soluble Silica (ppm)	2.17	3.81	1.11	2.83	2.21	2.27	1.86	1.88
Chloride (ppm)	1.83	1.89	3.92	2.32	2.15	1.75	2.11	2.2
Sulphate (ppm)	6.45	6.32	5.47	3.6	6.2	6.33	8.21	8.6
TIC (mg/L)	10	12	9	12.3	9.9	9.8	9.4	9.4
TOC (mg/L)	6.3	6.3	5.3	5.6	5.7	5.7	6	6
Hardness (mg/L-CaCO3)	41	44	43	51	47	45	46	47
Calcium (ppm)	12	13	12.5	15	14	13	13	13
Magnesium (ppm)	2.73	2.93	2.9	3.3	3	3	3.45	3.65
Sodium (ppm)	2.3	2.38	2.38	2.48	2.2	2.1	2.5	2.9
Potassium (ppm)	0.74	0.77	0.75	0.9	0.7	0.72	0.75	0.75
Aluminum (ppm)	<1	1	1	1	<1	1	<1	1
Manganese (ppm)	<0.05	0.3	0.05	2.2	0.05	0.05	<0.05	0.05
Zinc (ppm)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Copper (ppb)	3	4	<1	1	<1	5	<1	1
Nickel (ppb)	<5	<5	<5	<5	<5	<5		
Arsenic (ppb)	<1	1	1	7	<1	1	<1	1
Selenium (ppb)	<1	1	<1	2	<1	1	<1	1
Suspended Iron (ppm)	0.01	0.01	0.08	2.5	0.01	0.009	0.007	0.011
Dissolved Iron (ppm)	0.05	0.14	1	1.03	0.06	0.12	<0.05	0.05
Mercury (ppb)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

APPENDIX 1
CONTINUED

ICY LAKE	MAY		AUGUST		OCTOBER		MARCH	
	SURFACE	BOTTOM	SURFACE	BOTTOM	SURFACE	BOTTOM	SURFACE	BOTTOM
pH	7.4	6.6	7.7	7	7.5	7.6	7.4	7.5
Conductivity (mS/m)	8.79	9.93	10.5	10.9	10.6	10.6	10.1	10.7
Tot Alkalinity (mg/L-CaCO3)	38.04	39.32	38		40		42	
Turbidity (NTU)	0.7	2.4	0.45	1.4	1.1	1.1	0.23	0.22
TSS @105 (mg/L)	1	5	3.2	10	2.4	<	1.2	2
TSS @550 (mg/L)			2	6.4	2	<	1.2	1.6
TDS @105 (mg/L)	67	71	60	84	56	64	72	70
TDS @550 (mg/L)			52	54	38	42	60	50
Total Phosphorus (ppb)	12	44	14	38	20	20	9	19
Soluble Phosphorus (ppb)	<5	6	<5	<	10	11	<5	<5
Kjeldahl Nitrogen (ppm)	0.42	0.52	0.34	0.36	0.24	0.19	0.34	0.15
Nitrite (ppm-NO2)	<0.01	<0.0	0.04	0.13	<0.01	<0.0	<0.01	<0.01
Nitrate (ppm-NO3)	0.04	0.01	0.05	0.29	<0.01	0.01	0.03	0.01
Ammonia (ppb)	<10	100	<10	<1	19	46	26	28
Total Silica (ppm)	1.35	1.6	1.85	2.8	1.7	2.35	1.92	2.2
Soluble Silica (ppm)	0.9	1.57	1.89	2.77	1.7	2.03	1.82	1.79
Chloride (ppm)	1.99	2	2.08	2.16	0.58	2.93	2.37	2.38
Sulphate (ppm)	6.5	7.41	6.06	5.02	2.1	6.22	8.48	7.57
TIC (mg/L)	11	11	9.3	10.4	10.1	10.2	9	9.4
TOC (mg/L)	6.2	6.7	5.8	5.8	5.9	6.2	6	6
Hardness (mg/L-CaCO3)	41	44	42	47	45	45	46	46
Calcium (ppm)	12	13	12	13.8	13	13	13	13
Magnesium (ppm)	2.71	2.98	2.9	3.2	3	3	3.42	3.33
Sodium (ppm)	2.29	2.49	2.4	2.45	2.4	2.3	2.9	2.9
Potassium (ppm)	0.72	0.75	0.74	0.86	0.73	0.7	0.76	0.78
Aluminum (ppm)	<1	<	1	1	<1	<	<1	<1
Manganese (ppm)	<0.05	<0.0	<0.04	2.13	0.09	0.1	<0.05	<0.05
Zinc (ppm)	<0.02	<0.0	<0.02	<0.0	<0.02	<0.0	<0.02	<0.02
Copper (ppb)	4	5	1	2	<1	<	3	<1
Nickel (ppb)	<5	<	<5	<	<5	<	<50	<50
Arsenic (ppb)	<1	<	<1	5	2	<	<1	<1
Selenium (ppb)	<1	3.5	2	2	<1	1	<1	<1
Suspended Iron (ppm)	0.007	0.024	1	9	0.01	0.008	0.009	0.005
Dissolved Iron (ppm)	0.05	0.53	0.05	0.39	0.16	0.15	<0.05	<0.05
Mercury (ppb)	<0.2	<0.	<0.2	<0.	<0.2	<0.	<0.2	<0.2

APPENDIX 1
CONTINUED

ABIE LAKE	MAY SURFACE	MAY BOTTOM	AUGUST SURFACE	AUGUST BOTTOM	OCTOBER SURFACE	OCTOBER BOTTOM	MAR SURFACE
pH	7.6	7.5	7.7	7.6	7.5	7.6	
Conductivity (mS/m)	8.7	8.61	9.5	9.7	4.2	10.3	
Tot Alkalinity (mg/L-CaCO3)	38.74	37.62	38.5		38		
Turbidity (NTU)	1	1.8	0.69	0.57	0.62	0.67	
TSS @105 (mg/L)	2	1	2	2	<2	2	
TSS @550 (mg/L)			<1	<	<2	<2	
TDS @105 (mg/L)	65	70	64	62	12	66	
TDS @550 (mg/L)			22	14	11	42	
Total Phosphorus (ppb)	23	14	18	11	14	21	
Soluble Phosphorus (ppb)	<5	<	<5	<	5	11	
Kjeldahl Nitrogen (ppm)	0.71	0.51	0.3	0.24	0.32	0.29	
Nitrite (ppm-NO2)	<0.01	<0.0	0.03	0.03	<0.01	<0.01	
Nitrate (ppm-NO3)	0.04	0.03	0.02	0.02	<0.01	0.02	
Ammonia (ppb)	10	30	<10	<1	65	84	
Total Silica (ppm)	2.5	2.7	1	1.9	2.4	2.45	
Soluble Silica (ppm)	2.23	2.72	1.46	2.06	2.36	2.31	
Chloride (ppm)	1.97	1.98	1.87	2.05	2.46	1.96	
Sulphate (ppm)	6.32	6.55	6.36	5.97	5.98	5.84	
TIC (mg/L)	10	11	9.2	9	3.5	9.9	
TOC (mg/L)	7	6.8	5.5	5.6	3.2	6.03	
Hardness (mg/L-CaCO3)	41	41	42	42	44	44	
Calcium (ppm)	12	12	12	12	13	13	
Magnesium (ppm)	2.73	2.73	2.9	2.9	2.9	2.9	
Sodium (ppm)	2.31	2.29	2.7	2.6	2.4	2.2	
Potassium (ppm)	0.75	0.74	0.73	0.7	0.7	0.69	
Aluminum (ppm)	<1	<	1	1	<1	<1	
Manganese (ppm)	<0.05	0.05	0.06	0.1	<0.05	<0.05	
Zinc (ppm)	<0.02	<0.0	<0.02	<0.0	<0.02	<0.02	
Copper (ppb)	4	3	<1	<	<1	<1	
Nickel (ppb)	<5	<	<5	<	<5	<5	
Arsenic (ppb)	<1	<	<1	<	<1	<1	
Selenium (ppb)	<1	2	<1	2	<1	1	
Suspended Iron (ppm)	0.012	0.008	0.05	0.05	0.005	0.008	
Dissolved Iron (ppm)	0.08	0.08	<0.5	<0.	0.07	0.07	
Mercury (ppb)	<0.2	<0.	<0.2	<0.	<0.2	<0.2	

APPENDIX 1
CONTINUED

SLUSH LAKE	MAY SURFACE	MAY BOTTOM	AUGUST SURFACE	AUGUST BOTTOM	OCTOBER SURFACE	OCTOBER BOTTOM	MAR SURFACE
pH	7.3	6.8	7.8	6.8	7.4	7.5	
Conductivity (mS/m)	4.74	4.92	5.4	5.5	5.3	5.2	
Tot Alkalinity (mg/L-CaCO3)	20.72	20.56	23		21		
Turbidity (NTU)	0.95	0.8	0.47	0.92	0.76	1	
TSS @105 (mg/L)	<1	1	1.2	1.6	<2	<2	
TSS @550 (mg/L)			<1	<	<2	<2	
TDS @105 (mg/L)	45	48	34	24	34	41	
TDS @550 (mg/L)			24	4	16	21	
Total Phosphorus (ppb)	<5	12	6	19	13	19	
Soluble Phosphorus (ppb)	<5	<	<5	<	9	7	
Kjeldahl Nitrogen (ppm)	0.56	0.5	0.21	0.3	0.26	0.15	
Nitrite (ppm-NO2)	<0.01	<0.0	0.04	0.04	<0.01	<0.01	
Nitrate (ppm-NO3)	<0.01	<0.0	0.03	0.03	<0.01	<0.01	
Ammonia (ppb)	<10	20	40	<1	19	11	
Total Silica (ppm)	2.2	2.8	0.6	1.6	1.7	2.65	
Soluble Silica (ppm)	2.07	2.75	0.63	1	1.7	2.55	
Chloride (ppm)	0.3	0.3	0.46	0.5	0.58	0.252	
Sulphate (ppm)	2.1	2.21	2.07	2.04	2.1	1.97	
TIC (mg/L)	6.2	7.1	5.2	5.5	5.3	6	
TOC (mg/L)	7.2	7.3	6.1	5.7	6.6	6.1	
Hardress (mg/L-CaCO3)	23	23	22	23	24	25	
Calcium (ppm)	7.9	7.8	7.5	7.8	8	8.5	
Magnesium (ppm)	0.94	1	0.9	0.93	0.96	0.99	
Sodium (ppm)	0.69	0.64	0.69	0.7	0.65	0.65	
Potassium (ppm)	0.42	0.42	0.35	0.4	0.33	0.36	
Aluminum (ppm)	<1	<	1	1	<1	<1	
Manganese (ppm)	<0.05	0.05	<0.05	0.05	<0.05	0.09	
Zinc (ppm)	<0.02	<0.0	<0.02	<0.0	<0.02	<0.02	
Copper (ppb)	4	4	<1	<	<1	<1	
Nickel (ppb)	<5	<	<5	<	<5	<5	
Arsenic (ppb)	<1	<	<1	<	<1	<1	
Selenium (ppb)	4	1.3	<1	3	<1	<1	
Suspended Iron (ppm)	0.006	0.005	1	<0.	0.005	0.005	
Dissolved Iron (ppm)	0.05	0.16	<0.05	0.05	0.05	0.23	
Mercury (ppb)	<0.2	<0.	<0.2	<0.	<0.2	<0.2	

APPENDIX 1
CONTINUED

MARMION SOUTH	MAY		AUGUST		OCTOBER		MARCH	
	SURFACE	BOTTOM	SURFACE	BOTTOM	SURFACE	BOTTOM	SURFACE	BOTTOM
pH	7.4	6.9	7.1	6.8	7.5	7.5	7.4	7.2
Conductivity (mS/m)	9.03	9.48	9.3	10.7	9.8	9.7	10.2	10
Tot Alkalinity (mg/L-CaCO3)	33.94	34.1	36		36		42	
Turbidity (NTU)	0.8	0.9	0.52	0.41	0.85	0.8	0.18	0.22
TSS @105 (mg/L)	<1	<	2.8	2.8	<2	2.4	0.8	1.2
TSS @550 (mg/L)			1.2	1.6	<2	<	0.4	0.8
TDS @105 (mg/L)	65	65	70	70	56	63	74	64
TDS @550 (mg/L)			44	52	40	44	66	60
Total Phosphorus (ppb)	13	14	14	18	16	20	20	16
Soluble Phosphorus (ppb)	<5	<	<5	<	9	15	10	<5
Kjeldahl Nitrogen (ppm)	0.55	0.58	0.24	0.23	0.41	0.36	0.28	0.67
Nitrite (ppm-NO2)	<0.01	<0.0	0.04	0.04	0.02	0.01	<0.01	<0.01
Nitrate (ppm-NO3)	<0.01	0.01	<0.01	<0.0	0.01	0.04	0.28	0.28
Ammonia (ppb)	20	<1	<10	30	27	34	<10	10
Total Silica (ppm)	2.2	3.5	1.8	4.52	2.4	2.85	2.06	2.5
Soluble Silica (ppm)	1.94	3.65	1.83	4.34	2.28	2.83	2	2.41
Chloride (ppm)	1.96	1.98	1.71	2.26	1.6	1.58	2.11	1.99
Sulphate (ppm)	6.3	6.7	6.19	6.73	5.88	5.84	7.86	7.61
TIC (mg/L)	10	10	8.6	8.9	9.5	9.5	9.9	9.6
TOC (mg/L)	5.6	6.5	5.7	5.3	5.8	5.8	6	6
Hardness (mg/L-CaCO3)	41	41	40	41	42	42	54	48
Calcium (ppm)	12	12	11.5	12	12	12	14	14
Magnesium (ppm)	2.78	2.79	2.8	2.8	2.8	2.9	4.8	3.2
Sodium (ppm)	2.25	2.23	2.32	2.38	2.1	2.1	2.5	2.8
Potassium (ppm)	0.71	0.73	0.7	0.76	0.68	0.69	0.88	0.73
Aluminum (ppm)	<1	<	1	1	<1	<	<1	<1
Manganese (ppm)	<0.05	0.05	0.06	0.13	0.2	0.36	<0.05	0.1
Zinc (ppm)	<0.02	<0.0	<0.02	<0.0	<0.02	<0.0	<0.02	<0.02
Copper (ppb)	4	2	2	<	<1	<	<1	1
Nickel (ppb)	<5	<	<5	<	<5	<	<50	<50
Arsenic (ppb)	<1	<	<1	<	<1	<	<1	<1
Selenium (ppb)	<1	2	<1	<	<1	<	<1	<1
Suspended Iron (ppm)	0.005	0.007	<0.5	<0.	0.005	0.006	0.009	0.014
Dissolved Iron (ppm)	0.05	0.05	<0.05	0.05	0.06	0.06	<0.05	<0.05
Mercury (ppb)	<0.2	<0.	<0.2	<0.	<0.2	<0.	<0.2	<0.2

APPENDIX 1
CONTINUED

MARMION NORTH	MAY		AUGUST		OCTOBER		MARCH	
	SURFACE	BOTTOM	SURFACE	BOTTOM	SURFACE	BOTTOM	SURFACE	BOTTOM
pH	7.3	6.7	7.5	7	7.5	7.7	7.3	6.5
Conductivity (mS/m)	8.67	8.61	9.7	9.8	9.5	9.6	9.4	10.3
Tot Alkalinity (mg/L-CaCO3)	34.6	33.18	37		36		41	
Turbidity (NTU)	0.4	1.1	0.35	0.44	0.85	0.77	0.19	2.2
TSS @105 (mg/L)	<1	<	1.6	1.6	<2	<	0.8	1.6
TSS @550 (mg/L)			<1	<	<2	<	0.4	1.6
TDS @105 (mg/L)	62	62	62	44	58	61	66	56
TDS @550 (mg/L)			46	18	38	41	56	56
Total Phosphorus (ppb)	11	15	8	14	19	19	15	15
Soluble Phosphorus (ppb)	<5	<	<5	<	9	10	<5	<5
Kjeldahl Nitrogen (ppm)	0.62	0.51	0.23	0.2	0.38	0.42	0.34	0.29
Nitrite (ppm-NO2)	<0.01	<0.0	0.04	0.04	0.01	0.01	<0.01	<0.01
Nitrate (ppm-NO3)	0.01	0.01	<0.01	<0.0	<0.01	<0.0	0.09	1.16
Ammonia (ppb)	30	20	40	10	27	37	<10	<10
Total Silica (ppm)	1.9	2.75	1.35	2.4	2.65	2.85	1.9	4.35
Soluble Silica (ppm)	1.88	2.77	1.37	2.69	2.77	2.75	1.83	4.17
Chloride (ppm)	1.77	1.72	1.84	1.71	1.5	1.49	1.82	1.97
Sulphate (ppm)	5.3	5.4	5.72	6	5.57	5.46	6.93	6.98
TIC (mg/L)	10	11	8.6	8.7	9.3	9.2	8.7	10.4
TOC (mg/L)	5.4	5.5	5.3	5.4	5.7	5.6	6	6
Hardness (mg/L-CaCO3)	39	39	40	42	42	42	50	54
Calcium (ppm)	11	11	11.5	12	12	12	13	12
Magnesium (ppm)	2.79	2.78	2.8	2.8	2.8	2.8	4.34	5.83
Sodium (ppm)	2.07	2.06	2.13	2.15	2	2	2.4	2.4
Potassium (ppm)	0.79	0.71	0.7	0.71	0.66	0.66	0.75	0.76
Aluminum (ppm)	<1	<	1	1	<1	<	<1	<1
Manganese (ppm)	<0.05	0.18	<0.05	0.1	0.2	0.18	<0.05	0.45
Zinc (ppm)	<0.02	<0.0	<0.02	<0.0	<0.02	<0.0	<0.02	<0.02
Copper (ppb)	12	5	4	5	<1	<	2	<1
Nickel (ppb)	<5	<	<5	<	<5	<	<50	<50
Arsenic (ppb)	<1	<	<1	<	<1	<	<1	<1
Selenium (ppb)	1.5	<	<1	<	<1	<	<1	<1
Suspended Iron (ppm)	0.003	0.009	<0.5	<0.	0.004	0.009	0.006	0.007
Dissolved Iron (ppm)	<0.05	0.15	0.07	0.08	0.15	0.13	<0.05	0.12
Mercury (ppb)	<0.2	<0.	<0.2	<0.	<0.2	<0.	<0.2	<0.2

APPENDIX 1
CONTINUED

ANDERSON DAM	MAY		AUGUST		OCTOBER		MARCH	
	SURFACE	BOTTOM	SURFACE	BOTTOM	SURFACE	BOTTOM	SURFACE	BOTTOM
pH	7.5	7.4	7.6	7.4	7.9	7.7	7.3	7
Conductivity (mS/m)	8.4	9.66	9.4	9.4	9.7	9.8	9.7	10.2
Tot Alkalinity (mg/L-CaCO3)	36.16	36.38	37.5		37		42	
Turbidity (NTU)	0.8	4.2	2.25	2.6	1	2.1	0.19	0.3
TSS @105 (mg/L)	3	6	2.8	1.6	4.8	4.8	1.2	1.6
TSS @550 (mg/L)			1.2	<	4.2	4	<0.4	1.2
TDS @105 (mg/L)	80	125	42	46	60	58	66	60
TDS @550 (mg/L)			8	16	45	41	48	52
Total Phosphorus (ppb)	<5	19	17	22	27	24	8	13
Soluble Phosphorus (ppb)	<5	14	<5	<	16	12	<5	5
Kjeldahl Nitrogen (ppm)	0.58	0.56	0.28	0.31	0.22	0.3	0.19	0.37
Nitrite (ppm-NO2)	<0.01	<0.0	0.04	0.04	0.01	<0.0	0.11	<0.01
Nitrate (ppm-NO3)	0.01	<0.0	<0.01	<0.0	<0.01	<0.0	<0.01	0.45
Ammonia (ppb)	<10	<1	10	20	43	49	60	<10
Total Silica (ppm)	2	1.45	2.4	2.25	2.55	2.75	2.14	3.47
Soluble Silica (ppm)	2	1.4	2.29	2.57	2.54	2.66	1.97	3.23
Chloride (ppm)	1.76	1.71	1.67	1.67	1.53	2.04	2	1.91
Sulphate (ppm)	5.9	5.98	5.52	5.7	5.92	5.66	7.37	7.08
TIC (mg/L)	10.5	10	9	9.3	9.5	9.5	9.4	11.4
TOC (mg/L)	6.8	6.1	5.4	5.3	5.7	5.7	7	5
Hardness (mg/L-CaCO3)	41	39	42	42	45	42	45	51
Calcium (ppm)	12	11	12	12	13	12	12	14
Magnesium (ppm)	2.78	2.74	2.9	3	3	2.9	3.77	3.91
Sodium (ppm)	2.13	2.1	2.18	2.27	2	2	2.5	2.5
Potassium (ppm)	0.71	0.78	0.72	0.75	0.72	0.72	0.8	0.79
Aluminum (ppm)	<1	<	1	1	<1	<	<1	<1
Manganese (ppm)	<0.05	0.63	0.06	0.34	<0.05	<0.0	0.05	0.05
Zinc (ppm)	<0.02	<0.0	<0.02	<0.0	<0.02	<0.0	<0.02	<0.02
Copper (ppb)	2	12	2	2	<1	<	2	<1
Nickel (ppb)	<5	<	<5	<	<5	<	<50	<50
Arsenic (ppb)	<1	<	<1	<	<1	<	<1	<1
Selenium (ppb)	<1	1.5	<1	<	1	<	<1	<1
Suspended Iron (ppm)	0.001	0.084	2.5	9	0.018	0.031	0.007	0.009
Dissolved Iron (ppm)	0.06	0.25	0.11	0.19	0.13	0.14	-0.05	0.1
Mercury (ppb)	<0.2	<0.	<0.2	<0.	<0.2	<0.	<0.2	<0.2

APPENDIX 1
CONTINUED

MOOSE LAKE	MAY SURFACE	MAY BOTTOM	AUGUST SURFACE	AUGUST BOTTOM	OCTOBER SURFACE	OCTOBER BOTTOM	MAR SURFACE
pH	7.5	6.9	7.5	7	7.5	7.6	
Conductivity (mS/m)	8.4	9.57	9.4	9.6		9.9	
Tot Alkalinity (mg/L-CaCO3)	35.74	37	38.5		37		
Turbidity (NTU)	0.7	0.6	0.69	0.54	0.5	0.71	
TSS @105 (mg/L)	2	<	2.8	2.4	8.6	<2	
TSS @550 (mg/L)			2	1.2	7.3	<2	
TDS @105 (mg/L)	67	68	44	54	9	59	
TDS @550 (mg/L)			22	20	<5	39	
Total Phosphorus (ppb)	6	7	16	12		22	
Soluble Phosphorus (ppb)	<5	<	<5	<5		16	
Kjeldahl Nitrogen (ppm)	0.64	0.59	0.19	0.4	0.28	0.25	
Nitrite (ppm-NO2)	<0.01	<0.0	0.03	0.04	<0.01	<0.01	
Nitrate (ppm-NO3)	0.01	0.18	0.02	0.4	0.04	0.05	
Ammonia (ppb)	20	<1	20	<1	47	46	
Total Silica (ppm)	2.3	3	1.8	1.85	2.25	2.5	
Soluble Silica (ppm)	2.38	3.09	1.89	1.71	2.26	2.52	
Chloride (ppm)	1.87	1.96	1.84	1.89	2.02	1.49	
Sulphate (ppm)	6.1	6.41	5.95	6.37	5.93	5.71	
TIC (mg/L)	10	10.4	8.8	9.2	2.2	9.6	
TOC (mg/L)	6.2	6.4	5.4	5.2	2.1	5.7	
Hardness (mg/L-CaCO3)	41	42	42	42	44	42	
Calcium (ppm)	12	12	12	12	13	12	
Magnesium (ppm)	2.8	2.89	2.8	2.9	2.9	2.9	
Sodium (ppm)	2.17	2.29	2.4	2.4	1.98	2	
Potassium (ppm)	0.74	0.75	0.71	0.76	0.7	0.72	
Aluminum (ppm)	<1	<	1	1	<1	<1	
Manganese (ppm)	<0.05	<0.0	<0.05	0.17	<0.05	<0.05	
Zinc (ppm)	<0.02	<0.0	<0.02	<0.0	<0.02	<0.02	
Copper (ppb)	9	2	<1	<	<1	<1	
Nickel (ppb)	<5	<	<5	<	<5	<5	
Arsenic (ppb)	<1	<	<1	<	<1	<1	
Selenium (ppb)	1.5	<	<1	<	<1	<1	
Suspended Iron (ppm)	0.007	0.009	<0.5	2.5	0.009	0.012	
Dissolved Iron (ppm)	0.1	0.05	0.05	0.08	0.05	0.05	
Mercury (ppb)	<0.2	<0.	<0.2	<0.	<0.2	<0.2	